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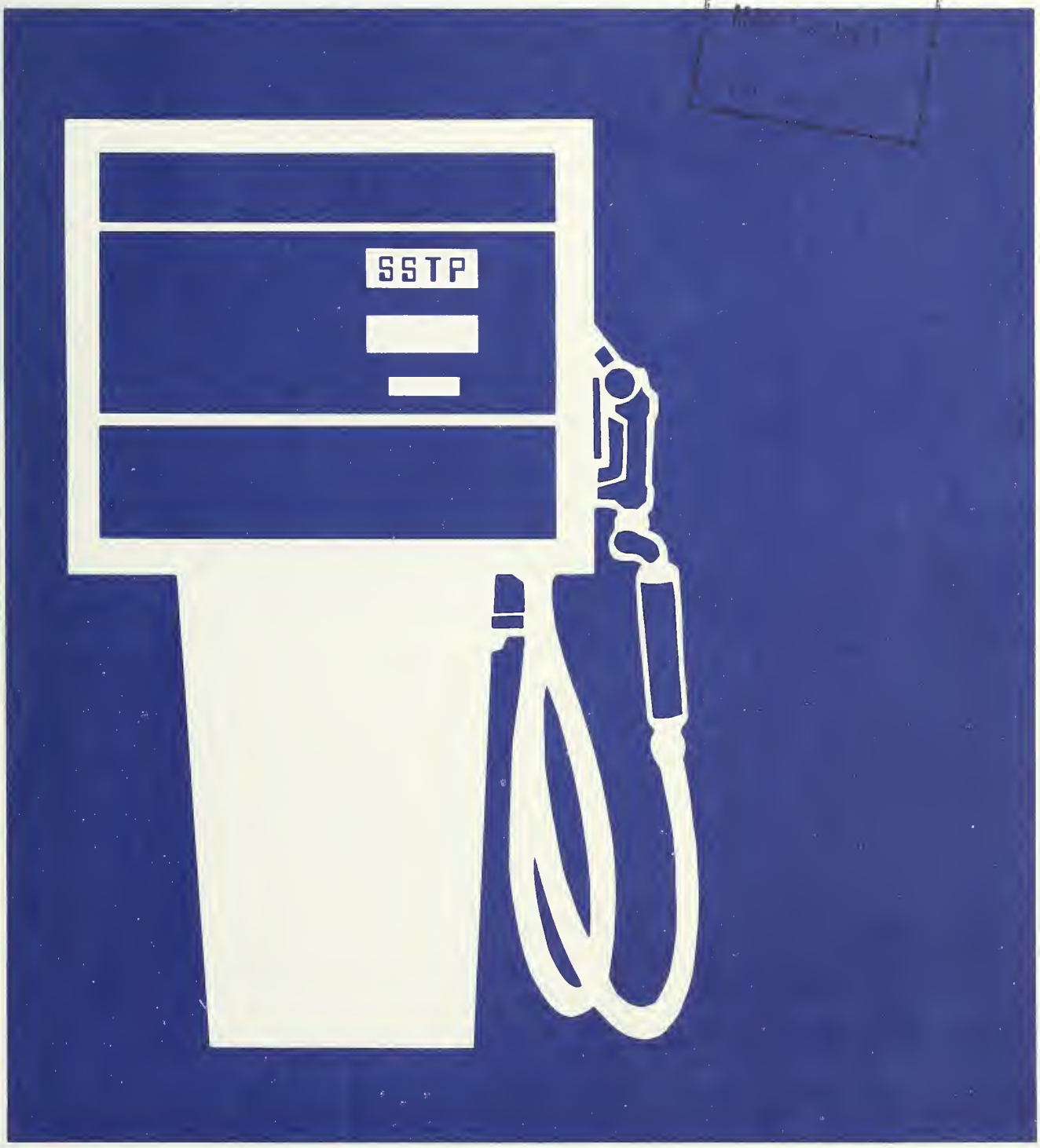
Transportation Energy Contingency Planning:

Quantifying the Need for Transit Actions

January 1983

DEPARTMENT OF
TRANSPORTATION



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Quantifying the Need for Transit Actions

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In cooperation with

Technology Sharing Program
Office of the Secretary of Transportation

DOT-I-83-02

FOREWORD

The decontrol of petroleum early in 1981 introduced a number of new factors into planning by transit operators. Removal of price controls and supply allocation rules meant that operators would have to compete in the market place for fuel supplies with other end users and that similar market mechanisms would be likely to influence both current and potential transit users. In order to prevent changes in these market-driven factors from negatively effecting transit operators, the Urban Mass Transportation Administration (UMTA) has been and will continue to encourage energy contingency planning.

In order to assist transit operators in carrying out this important activity, UMTA is developing a number of materials providing technical assistance. Prior reports in this series entitled Transportation Energy Contingency Planning have included A Guide for Transit Operators (DOT-I-82-12), Transit Fuel Supplies Under Decontrol (DOT-I-82-20) and Taxi and School Bus Use in Dallas-Fort Worth (DOT-I-82-38). This report, Quantifying the Need For Transit Actions is designed to provide further guidance for transit operators designing contingency response plans by providing additional quantitative criteria to assist in selecting planned measures. We believe it will provide useful further detail to the methods already available for developing these plans.

Additional copies of this report, or the others from this series, are available from our offices upon receipt of a self-addressed label, while supplies last. In addition, reports are available through the National Technical Information Service, Springfield, Virginia 22161. Please refer to UMTA-NY-09-8006-83-1 when requesting this report.

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ABSTRACT

This report provides a simple, rapid method for anticipating or reacting to a peak-hour transit capacity problem brought about by an energy shortfall. The first step is determining when peak-hour capacity should be increased on a given route. This is done through use of the Capacity Problem Index (CPI) developed here. A worksheet is provided for calculating the CPI, and the results lead the transit operator directly to recommendations for what should be done to increase peak-hour capacity. Three packages of recommendations are provided for use depending on the severity of the peak-hour capacity problem. The body of the report serves as a manual for transit operators wishing either to plan for various energy scenarios or to take action in a crisis. The appendices contain a more detailed analysis, including sections on the evaluation of peak-hour capacity-expending options, the responses of 45 transit operators to the 1979 energy shortfall, and the development of the Capacity Problem Index.

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1. INTRODUCTION: THE PROBLEM AND THE APPROACH

Transit operators generally make the decision concerning fleet size based upon the peak-hour demand for transit service. The actual fleet size is always somewhat higher than the number of vehicles needed to serve this demand, in order to allow for necessary maintenance and provide flexibility in the event of breakdowns. Nevertheless, it is fair to say that most transit systems operate at or near capacity during peak hours, and below capacity at other times.

The 1973-74 and 1979 gasoline shortfalls have shown that demand for transit service can rise sharply in a very short time period during a fuel supply cutoff. This increased demand is focused in the morning and afternoon peak hours. The major problem is then that significant ridership increases are concentrated in a time period when transit systems are least able to accommodate more riders.

This problem is compounded by the fact that transit ridership during an energy crisis is at an artificially high level. Once the crisis subsides, ridership returns to a normal (albeit somewhat higher) level. This means that the transit system must cope with a <u>temporary</u> increase of significant magnitude. The time frame for implementing actions to increase capacity thus gains added importance: the crisis may be over by the time long term actions are fully implemented.

The challenge to transit operators in a crisis situation is to meet rapidly-increasing demand, focused upon the time period when there is little excess

capacity, knowing that the situation is likely to be temporary. Until very recently, there was little help available in the transit literature; what information was available was scattered throughout disparate publications and did not focus on crisis situations in which problems are most acute.

While ridership levels in a crisis situation are artificially high, it is logical to expect that the number of new riders who continue to use transit after the crisis subsides is related to the quality of transit service during the crisis. Since much of the increased ridership is focused on the peak hour, the quality and quantity of peak transit service is particularly significant. A previous study encompassing 66 urbanized areas nationwide indicated that the capacity of a transit system may influence its ability to attract riders during an energy shortfall (4). The ability of transit operators to meet large, quick, and temporary increases in peak demand therefore affects the community's ability to adjust to an energy crisis as well as the long-range health of the transit system.

The purpose of this study is to guide transit operators in making decisions regarding peak-hour transit capacity in a crisis. By means of the Capacity Problem Index (CPI) developed here, the operator can gauge <u>when peak-hour capacity should be increased</u>, and can then determine <u>what actions should be taken</u> by consulting the packages recommended for various crisis levels.

Packages of capacity-expanding options are assembled from options identified in the transit literature and in energy conservation and contingency plans. While short-range options are generally most appropriate for crisis situations, options involving a longer time frame are also examined because

implementation time can be cut with effective pre-crisis planning. Evaluation of these options are based on several criteria such as feasibility, cost, effectiveness, required lead time, and usefulness in different degrees of a crisis.

One of the early observations apparent in evaluating capacity-increasing options is that there is no one widely-accepted definition of transit capacity. Highway capacity is generally expressed in terms of vehicles per lane-hour. While transit capacity is dependent to some degree on the highway infrastructure, it is more directly related to the number of transit vehicles and particularly to the number of available spaces (seats plus the acceptable number of standees). The variable used to measure peak-hour transit capacity in this report is the daily number of available spaces during the peak hour. By this definition, peak hour transit capacity can be increased by increasing the number of seats in the peak hour, by allowing more standees, or by reducing the peak demand/space ratio.

In this report, the severity of an energy crisis is measured by the percentage shortfall in gasoline supply. A minor crisis is defined as a shortfall of less than 10%. A moderate crisis involves a shortfall of between 10% and 20%; both 1973-74 and 1979 crises fall into this category. A severe crisis is defined as a shortfall of greater than 20%. Options considered appropriate for a particular degree of severity may also be considered appropriate for more severe crises, unless otherwise noted in the text.

In order to aid in the evaluation of capacity-increasing options, a short survey was sent to a number of transit operators across the country. The

survey asked about actions taken during the 1979 energy crisis, problems encountered, and options recommended for similar situations in the future. The 66 urbanized area sample used in the previous study on ridership response to the 1979 crisis was enriched by the addition of 34 urbanized areas selected by a random sample stratified according to region and size of urbanized area. Of the resulting group of 102 transit operators in 100 urbanized areas, 45 systems in 44 urbanized areas responded to the survey. These responses provided a representative sample of all United States transit systems. Appendix A contains a copy of the survey, while Appendix C lists the urbanized areas included in the final sample.

The results of this survey are taken into consideration in evaluation of capacity-increasing options. The practical experiences of the operators in 1979 are an invaluable addition to the often theoretically-oriented observations in the literature. Taken together, they form a reliable basis for the evaluation of peak-hour capacity-increasing options for transit systems and for recommendations for action in future crises.

This report is designed for use by transit operators with peak-hour capacity problems. While it is written with a future energy crisis in mind, the options are appropriate for other emergency situations and also for alleviating non-emergency-related problems of this nature.

Following this introductory section, Section 2 addresses the question of when peak-hour transit capacity should be increased. A Capacity Problem Index is developed to answer this question. The index is policy-sensitive, utilizes available data on transit operations, and can either be used with

standardized values or adjusted to the local situation. A worksheet outlining a step-by-step application of the CPI is included in Section 2. Section 3 addresses the question of what should be done. After a brief discussion of the peak-hour capacity-expanding options and actions taken by transit operators during the 1979 energy crisis, packages of recommended actions are presented for various levels of crisis severity. Section 4 summarizes the report and offers conclusions for increasing peak-hour transit capacity.

While the body of this report provides a manual for measuring transit capacity in an energy shortfall, the appendices contain supporting documentation and are valuable for those wishing to examine the subject in greater detail.

Particular attention is drawn to Appendices D, E and F. Appendix D presents a full analysis of transit operators' perceptions of capacity problems in 1979 and actions taken in response to these problems. A thorough discussion and evaluation of options to increase peak-hour transit capacity is contained in Appendix E, which is a useful orientation for readers unfamiliar with transit operations. The derivation of the Capacity Problem Index is shown in Appendix F.

Several problems arise in attempting to increase peak-hour transit capacity during an energy shortfall. Crises of external origin are particularly difficult to anticipate. In 1973-74 and again in 1979, transit operators were unprepared for a rapid rise in ridership. Since 1979, many areas have drawn up detailed contingency plans for energy emergencies. However, given

the current fiscal atmosphere surrounding transit, it is not certain that these plans are still usable. As the immediacy of the energy crises recedes, perception of the relevance of these plans is dimmed. Since many capacity-increasing options require action in advance of a crisis, the next energy shortfall could find transit operators in essentially the same position as in 1973-74 and 1979. The time lag involved in fleet expansion or even service adjustments is a major underlying problem in implementing short-range expansion of transit capacity.

Along with the time-lag problem is the related issue of duration of the crisis. The two previous shortfalls have each lasted for less than six months. Along with exacerbating the time-lag problem, the short duration of previous crisis periods indicates that reversible actions are preferable to actions which commit the transit system to a sizable long-term capacity increase, since the merits of a long-term program to increase capacity should not be based solely on emergency needs. Of course, there is no guarantee that future energy shortfalls will last no longer than six months. It is still prudent, however, to plan short-term, reversible options. These can function as interim actions in an extended crisis period while new buses are ordered and long-term service changes are planned and implemented.

Increased personnel for operations and maintenance, expanded maintenance facilities, and additional storage facilities for vehicles and fuel may all be required in a crisis situation. Personnel training programs may be strained in an emergency by the number of new employees requiring training, and additional facilities may be difficult to obtain. One study suggests unused state right-of-way as a place for storing extra buses (7); depending

on the climate and season, this may work as a short-term solution. "Jobbing out", or using outside personnel or facilities to perform transit maintenance, is another short-term option, although the reliability of such work is unknown. These issues must be addressed in order to insure the maximum effectiveness of other capacity-increasing options.

Diesel fuel availability is no longer guaranteed in a shortfall situation. With the recent Presidential veto of enabling emergency energy legislation, transit operators are not assured of sufficient fuel supplies. Given that the current administration is firmly committed to reliance on the free market for fuel allocation in a shortfall, transit operators must take steps in advance of a crisis to ensure that fuel supplies will be adequate.

Institutional and regulatory constraints are a significant factor in terms of the ability to implement certain options. Section 13(c) of the 1964 Urban Mass Transportation Assistance Act effectively guarantees that labor's position will not be adversely affected on any system receiving federal support. Transit labor unions must be consulted on changes in hiring practices or work rules and their approval must be secured. In certain cases there are also legal barriers to be overcome and regulatory procedures to be followed before implementing a given action. In the majority of cases, these types of constraints do not make implementation impossible. Rather, they require the operator to make agreements and arrangements prior to a crisis situation. Most contingency plans make this point clearly, but it deserves additional emphasis here.

Political considerations are also important. Transit operators must communicate to elected officials the need to remove certain legal and regulatory constraints in a crisis situation. There are likely to be unpopular but necessary policy decisions, and the rationale behind these must also be communicated. However, this is a difference only in degree from day-to-day procedures; the groundwork for these communication channels is laid during normal operations.

Finally, there is the funding question. In an energy shortfall, rising fuel prices will strain the fiscal resources of the transit operator. Expanding transit capacity under these circumstances, coupled with likely rises in diesel fuel prices, will almost certainly put the transit operator over budget. The source for these additional funds is not clear, particularly in an era of decreased funding for transit. Fiscal capacity may well be the ultimate limit to the expansion of transit capacity.

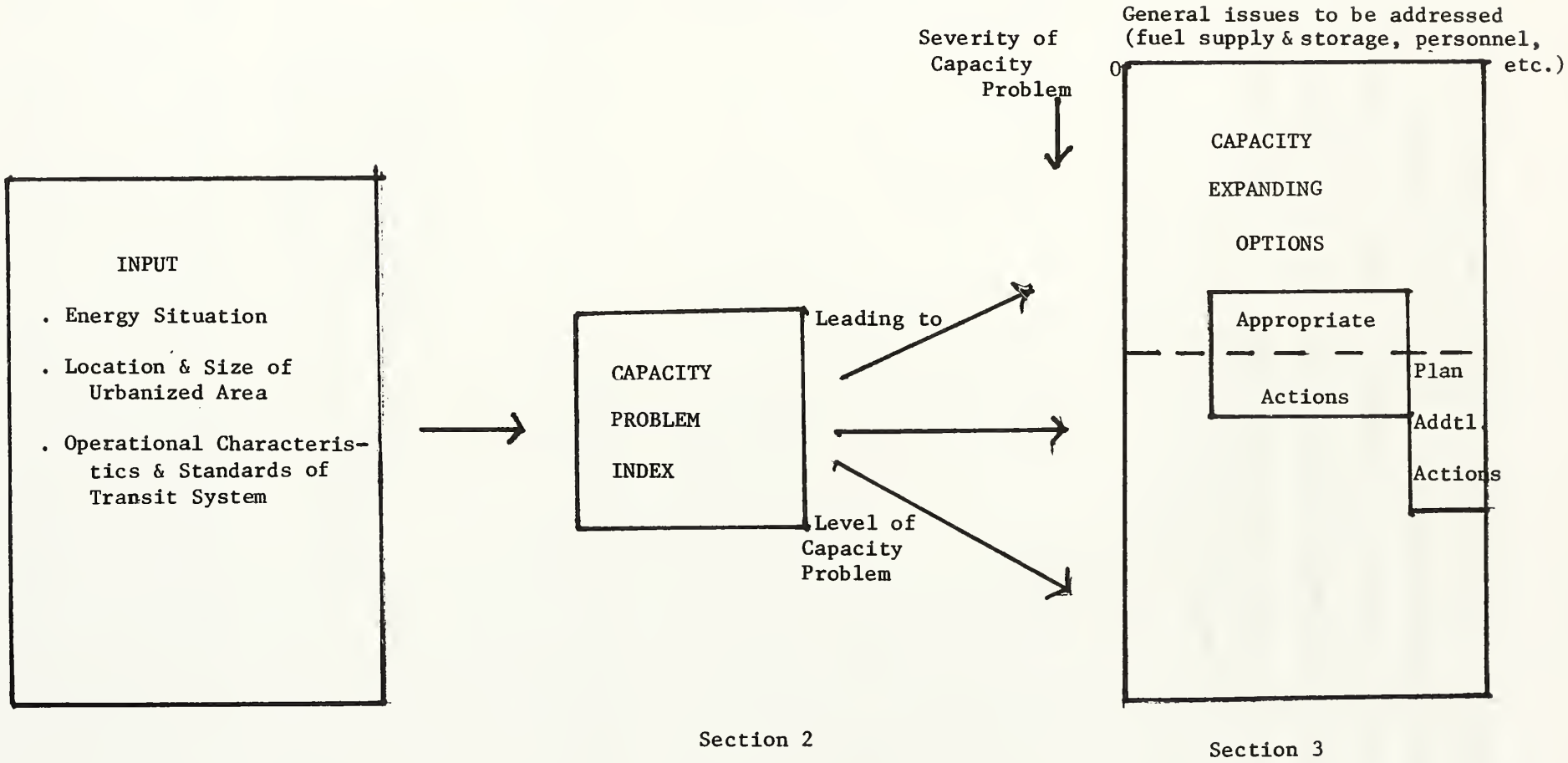
The preceding paragraphs have mentioned several issues involved in increasing peak-hour transit capacity. A summary checklist of these issues includes:

- need for new personnel
- expanded maintenance
- increased vehicle and fuel storage
- fuel availability
- institutional and regulatory constraints
- political considerations
- funding sources

These issues must be addressed in advance of a crisis. As a manual for increasing transit capacity in an energy shortfall, this report assumes that these issues are or will be addressed elsewhere. While Appendix E discusses some of these issues in presenting and evaluating capacity-increasing

options, other sections of a local energy contingency plan should provide more detailed information on these issues. This report is structured in such a way that a transit operator can determine both the point at which his system will experience a peak-period capacity problem and the severity of that problem, and can then turn to appropriate actions to increase peak-hour capacity. Figure 1.1 outlines the general use of this report.

FIGURE 1.1 -GENERAL OUTLINE OF STRUCTURE AND USE OF THIS MANUAL



2. WHEN TO INCREASE CAPACITY: THE CAPACITY PROBLEM INDEX

This section guides the transit operator in making the decision when to increase peak-period capacity. This is done through use of the Capacity Problem Index (CPI), which measures the levels of ridership increase and gasoline shortfall at which a capacity problem will occur. Appendix F contains the derivation of the index and should be consulted if more detailed information is required.

Since capacity problems vary across routes in the system, the most crowded route or set of routes with similar characteristics can be selected for the analysis. Similarly, capacity problems are likely to occur or be most severe in the peak hour (or even peak half-hour or 15 minutes); examination of peak-period data for various transit properties indicates that the peak period is defined too broadly to pinpoint these problems. Therefore, the CPI is best applied at the route level using peak-hour data (shorter time periods are also appropriate).

The magnitude of peak-hour ridership increases and the excess transit capacity available in the peak-hour are the determining factors in assessing whether a transit system does or will experience a peak-hour capacity problem. The index requires as input three data points:

- the current peak load factor for the route (riders per seat in the peak hour)
- the acceptable peak load factor for the route
- the proportion of daily ridership carried in the peak hour.

The percentage increase in overall ridership (R) that will trigger a peak-hour capacity problem can be expressed as:

$$R = \frac{(APL-PL) \times (200) \times (p)}{PL} \qquad (2.1)$$

where APL is the acceptable peak load factor for the route

PL is the current peak load factor on the route

p is the proportion of daily ridership carried in the peak hour.

See Appendix F for the derivation of this formula. Equation 2.1 is the form which the Capacity Problem Index takes to determine the critical level of ridership increase. The CPI may also be used to determine the magnitude of gasoline shortfall which will trigger a peak-hour capacity problem. A previous study related changes in transit ridership to changes in gasoline supply for various system sizes and regions of the country through the use of cross-elasticities (4). Although these cross-elasticities, listed in Table 2.1, were developed at a very aggregate level, they may be used to give a rough estimate of the percentage shortfall (G) which will trigger a peak-hour capacity problem.

$$G = \frac{R}{e} = \frac{(APL-PL) \times (200) \times (p)}{(PL) \times (e)} \qquad (2.2)$$

where e is the appropriate cross-elasticity from Table 2.1. Equation 2.2 is the form which the Capacity Problem Index takes to determine the critical level of gasoline shortfall.

Equations 2.1 and 2.2 can be converted to worksheet form, which is generally easier to use. A sample worksheet is presented here. This worksheet can be

TABLE 2.1

CROSS-ELASTICITIES OF TRANSIT RIDERSHIP WITH RESPECT TO GASOLINE SUPPLY, BY REGION AND SYSTEM SIZE

Region[1]	System Size[2]	Cross-Elasticity
Northeast	Large	-0.45
	Small	-3.40
	All Systems	-0.48
South	Large	-0.87
	Small	-0.98
	All Systems	-0.90
North Central	Large	-0.66
	Small	-1.57
	All Systems	-0.69
West	Large	-2.55
	Small	-4.99
	All Systems	-2.79
All Regions	Large	-0.68
	Small	-2.11
	All Systems	-0.75

1. See Appendix B for a map defining regions of the country.

2. System size was determined by peak-hour vehicle requirement, with 100 vehicles as the dividing line between large and small.

SOURCE: Boyle (4)

INSTRUCTIONS FOR CAPACITY PROBLEM INDEX WORKSHEET

1. Put the current peak load factor on the route in question on Line 1. This is determined by the number of passengers in the peak hour divided by the number of seats available in the peak hour.

2. Write the acceptable peak load factor on Line 2.

3. Subtract Line 1 from Line 2 and divide by Line 1. Enter the result on Line 3.

4. Enter the proportion of daily ridership which is carried during the peak hour on Line 4. A figure for the individual route is best, but the system-wide proportion is acceptable.

5. Multiply Line 3 by Line 4 by 200 and enter the result on Line 5. This is the overall ridership increase (expressed as a percentage) which will cause a peak hour capacity problem.

6. For crisis use, find the range of values below in which the number on Line 5 falls and follow the instructions. If you are directed to another page, you may find it easily by using the black tab next to the instruction. Look at the side of the report, find the other tab lined up with this one, and open to that page.

7. For pre-crisis use, select the appropriate cross-elasticity from Table 2.1 and enter it on Line 6. Appendix B gives the boundaries of the geographic regions, while a peak-hour vehicle requirement of 100 is the dividing line between large (≥ 100) and small (< 100) systems.

8. Divide Line 5 by Line 6 to find the level of gasoline shortfall that will cause a peak-hour capacity problem. Enter the result on Line 7.

9. Enter the gasoline shortfall for which you are making plans on Line 8.

10. Subtract Line 7 from Line 8 and enter the result on Line 9. Then find the range of values below in which the number on Line 9 falls and follow the instructions. If you are directed to another page, you may find it easily by using the black tab next to the instruction. Look at the side of the report, find the other tab lined up with this one, and open to that page.

FIGURE 2.1

CAPACITY PROBLEM INDEX WORKSHEET

Line 1	Current peak load factor (passengers per seat in peak hour)	1. _____
Line 2	Acceptable peak load factor	2. _____
Line 3	(Line 2 - Line 1) ÷ Line 1	3. _____
Line 4	Proportion of daily ridership carried in the peak hour	4. _____
Line 5	Critical ridership increase (Line 3 x 200 x Line 4)	5. _____%
	FOR CRISIS USE, SEE BELOW. CONTINUE FOR PRE-CRISIS USE	
Line 6	Appropriate cross-elasticity (Table 2.1)	6. _____
Line 7	Critical gasoline shortfall (Line 5 ÷ Line 6) x (-1)	7. _____%
Line 8	Anticipated gasoline shortfall for which you are making plans	8. _____%
Line 9	Difference between anticipated and critical shortfall (Line 8 - Line 7)	9. _____

	FOR PRE CRISIS USE	FOR CRISIS USE	INSTRUCTIONS
IF	Line 9 is:	Line 5 is:	
	Less than -10	Greater than 7.5	You should have no problem on this route, even with further increases.
	Between -10 and 0	Between 0 and 7.5	You have no problem on this route currently, but if the crisis worsens a problem may develop. Go to page31; you may wish to plan for these actions.
	Between 0 and 10	Between -7.5 & 0	You have a minor problem on this route; go to page31.
	Between 10 and 20	Between -15.0 & -7.5	You have a problem on this route; go to page33.
	Greater than 20	Less than -15.0	You have a serious problem on this route; go to page35.

used either in anticipation of a crisis or during a crisis. If used in anticipation of a crisis, line 8 of the worksheet can be changed to consider the effects of various energy scenarios and to see what actions might be required. Several or even all routes might be analyzed in advance of a crisis to see how extensive the effects of a given energy scenerio on the transit system as a whole might be; presumably a severe shortfall would have a critical effect on more routes than a minor or moderate shortfall. If the worksheet is used during a crisis, only lines 1 through 5 are needed. There is no need to use cross-elasticities during a crisis because the shortfall will already be affecting ridership. If line 5 is positive in a crisis, then the route is accommodating the increased ridership.

Once the worksheet calculations are done, instructions at the bottom of the page direct the operator to the appropriate place in Section 3. There the operator will find a package of actions appropriate for the situation. The tabs at the side of the page may be used for easy location of the appropriate package in Section 3.

Figure 2.2 is a summary sheet for the transit system as a whole. Each route analyzed can be entered on Figure 2.2, along with the CPI from the worksheet and the actions selected for implementation from the tables in Section 3. This summary sheet gives the transit operator an overall view of the system's needs. If the analysis is performed for all routes, the summary sheet might also indicate underutilized routes.

Use of the worksheet can be clarified by some examples. Suppose that an operator of a large transit system in the North Central region wishes to

FIGURE 2.2

TRANSIT SYSTEM SUMMARY SHEET - ACTIONS NEEDED BY ROUTE

Route No.	CPI	Action Needed

determine if the most crowded routes in the system would experience a peak-hour capacity problem. Assume the following values:

APL = 1.2
PL = 0.9
p = 0.2
e = -0.66 (from Table 2.1).

Example Worksheet 1 shows the results. Line 5 indicates that a 13.3% ridership increase would trigger a peak-hour capacity problem. Line 7 shows that a 20.2% gasoline shortfall is the critical level. If the operator wishes to test energy scenarios involving 10%, 15% and 20% shortfalls, he could plug these values into line 8. A 10% shortfall would yield a value of -10.2 on line 9, and the bottom of the worksheet indicates that the routes will not have any capacity problems. A 15% shortfall yields a value of -5.2 on line 9, while line 9 is -0.2 with a 20% shortfall. The bottom of the worksheet indicates that there is still no problem in both cases, but that a problem may develop. Using the tabs, the operator turns to the package of recommended actions for a minor crisis and plans for possible implementation of these actions. The planning process would have more urgency at the 20% shortfall level, since a value of -0.2 is near the boundary between no problem and a minor problem. At a shortfall level of 10% or 15%, however, the operator could feel secure that the routes could handle the problem.

As a second example, consider a small Southern system in the early stages of an energy crisis. On the system's major route, 5% standees has been considered an acceptable level of service during the peak hour, but the operator is now experiencing 25% standees. The value for p is 0.3. Example Worksheet 2 demonstrates the application of the CPI. The value of line 5 is -9.6, indicating a problem on this route. The tabs lead the operator to the package of recommended actions for a moderate crisis. After studying the

EXAMPLE 1

CAPACITY PROBLEM INDEX WORKSHEET

Line 1	Current peak load factor (passengers per seat in peak hour)	1.	0.9
Line 2	Acceptable peak load factor	2.	1.2
Line 3	(Line 2 - Line 1) ÷ Line 1	3.	.333
Line 4	Proportion of daily ridership carried in the peak hour	4.	0.2
Line 5	Critical ridership increase (Line 3 x 200 x Line 4)	5.	13.3 %
	FOR CRISIS USE, SEE BELOW. CONTINUE FOR PRE-CRISIS USE		
Line 6	Appropriate cross-elasticity (Table 2.1)	6.	-0.66
Line 7	Critical gasoline shortfall (Line 5 ÷ Line 6) x (-1)	7.	20.2 %
Line 8	Anticipated gasoline shortfall for which you are making plans	8.	10 | 15 | 20 %
Line 9	Difference between anticipated and critical shortfall (Line 8 - Line 7)	9.	-10.2 | -5.2 | -0.2

	FOR PRE CRISIS USE	FOR CRISIS USE	INSTRUCTIONS
IF	Line 9 is:	Line 5 is:	
	Less than -10	Greater than 7.5	You should have no problem on this route, even with further increases.
	Between -10 and 0	Between 0 and 7.5	You have no problem on this route currently, but if the crisis worsens a problem may develop. Go to page 31; you may wish to plan for these actions.
	Between 0 and 10	Between -7.5 & 0	You have a minor problem on this route; go to page 31.
	Between 10 and 20	Between -15.0 & -7.5	You have a problem on this route; go to page 33.
	Greater than 20	Less than -15.0	You have a serious problem on this route; go to page 35.

EXAMPLE 2

CAPACITY PROBLEM INDEX WORKSHEET

Line 1	Current peak load factor (passengers per seat in peak hour)	1. 1.25
Line 2	Acceptable peak load factor	2. 1.05
Line 3	(Line 2 - Line 1) ÷ Line 1	3. -0.16
Line 4	Proportion of daily ridership carried in the peak hour	4. 0.3
Line 5	Critical ridership increase (Line 3 x 200 x Line 4)	5. -9.6 %
	FOR CRISIS USE, SEE BELOW. CONTINUE FOR PRE-CRISIS USE	
Line 6	Appropriate cross-elasticity (Table 2.1)	6. _____
Line 7	Critical gasoline shortfall (Line 5 ÷ Line 6) x(-1)	7. _____ %
Line 8	Anticipated gasoline shortfall for which you are making plans	8. _____ %
Line 9	Difference between anticipated and critical shortfall (Line 8 - Line 7)	9. _____

	FOR PRE CRISIS USE	FOR CRISIS USE	INSTRUCTIONS
IF	Line 9 is:	Line 5 is:	
	Less than -10	Greater than 7.5	You should have no problem on this route, even with further increases.
	Between -10 and 0	Between 0 and 7.5	You have no problem on this route currently, but if the crisis worsens a problem may develop. Go to page 31; you may wish to plan for these actions.
	Between 0 and 10	Between -7.5 & 0	You have a minor problem on this route; go to page 31.
	Between 10 and 20	Between -15.0 & -7.5	You have a problem on this route; go to page 33.
	Greater than 20	Less than -15.0	You have a serious problem on this route; go to page 35.

EXAMPLE 3

CAPACITY PROBLEM INDEX WORKSHEET

Line 1	Current peak load factor (passengers per seat in peak hour)	1.	1.25
Line 2	Acceptable peak load factor	2.	1.30
Line 3	(Line 2 - Line 1) ÷ Line 1	3.	0.04
Line 4	Proportion of daily ridership carried in the peak hour	4.	0.3
Line 5	Critical ridership increase (Line 3 x 200 x Line 4)	5.	2.4 %
	FOR CRISIS USE, SEE BELOW. CONTINUE FOR PRE-CRISIS USE		
Line 6	Appropriate cross-elasticity (Table 2.1)	6.	_____
Line 7	Critical gasoline shortfall (Line 5 ÷ Line 6) x (-1)	7.	_____ %
Line 8	Anticipated gasoline shortfall for which you are making plans	8.	_____ %
Line 9	Difference between anticipated and critical shortfall (Line 8 - Line 7)	9.	_____

	FOR PRE CRISIS USE	FOR CRISIS USE	INSTRUCTIONS
IF	Line 9 is:	Line 5 is:	
	Less than -10	Greater than 7.5	You should have no problem on this route, even with further increases.
	Between -10 and 0	Between 0 and 7.5	You have no problem on this route currently, but if the crisis worsens a problem may develop. Go to page 31; you may wish to plan for these actions.
	Between 0 and 10	Between -7.5 & 0	You have a minor problem on this route; go to page 31.
	Between 10 and 20	Between -15.0 & -7.5	You have a problem on this route; go to page 33.
	Greater than 20	Less than -15.0	You have a serious problem on this route; go to page 35.

package, the operator decides to change the acceptable peak load factor to 1.3 as a first step. Example Worksheet 3 demonstrates the results of this action. Line 5 of Example Worksheet 3 reads 2.4, indicating that there route now has no peak capacity problem. It is suggested that the operator make plans using the package of recommended actions for a minor crisis, found using the tabs again. Having adjusted operating standards in response to the crisis, the operator now has some time to plan further actions while monitoring the shortfall situation and ridership levels on the route.

Note what has actually happened in this example. The operator has not increased peak-hour capacity in the sense of providing more seats. Rather, he has made a policy decision that, at this point in the crisis, more crowded buses are acceptable. As discussed in Appendix E, changing operating standards in this way has long-term repercussions in terms of quality of service and so may be appropriate only as a short-term stopgap action. However, changing operating standards was the action taken most often by transit operators in 1979 (see Section 3 and Appendix D), and indeed is the logical first step to take for two reasons. First, it costs nothing and is unlikely to cause any negative effects in the short run. Second, it gives the operator additional time to assess the situation and consider alternative actions.

The Capacity Problem Index provides the transit operator with a straightforward method of gauging the severity of peak-hour capacity problems caused by a present or future energy crisis. The tab system leads the operator to the appropriate package of recommended actions in Section 3. The index as well as the packages of actions in Section 3 have been developed out of the

experiences of operators during the 1979 energy shortfall, and so should provide reliable guidance for future contingencies. A detailed description and derivation of the Capacity Problem Index may be found in Appendix F.

This section has provided transit operators with a method to determine the point at which peak-hour capacity problems will occur. The following section examines what can be done when this point is reached.

3. WHAT TO DO: PACKAGES OF RECOMMENDED ACTIONS TO INCREASE PEAK-HOUR TRANSIT CAPACITY

The preceding section of this report provides a worksheet for the Capacity Problem Index in order to allow a transit operator to determine when peak-hour capacity should be increased. The tabs on that worksheet lead to the appropriate area of this section, where the operator will find packages of recommended actions for varying levels of severity of the capacity problem.

Before the packages are presented, a brief listing of capacity-expanding options and a summary of actions taken and recommended by transit operators in 1979 are given. The options have been drawn from reviews of the transit literature and of energy contingency plans, and are discussed in much greater detail in Appendix E. Table 3.1 summarizes the positive and negative aspects of each option.

Transit operators around the country were asked what they did in 1979 and what they would recommend in a future shortfall situation. Table 3.2 shows the number of operators taking and recommending various short-term options. Table 3.2 also includes estimates of the effectiveness and cost of each option, and briefly summarizes problems encountered in 1979. It should be noted here that for both increasing park-and-ride/express bus service and relaxing informal operating standards, there is a large difference between the number of systems taking such action in 1979 and the number recommending it for a future crisis. The high cost of increasing park-and-ride/express bus service may well have discouraged operators from recommending it. Relaxing informal operating standards could lower the quality of transit service, and operators' reluctance to recommend this may stem from a concern

TABLE 3.1

SUMMARY OF PEAK-HOUR CAPACITY - EXPANDING OPTIONS

Option	Positive Aspects	Negative Aspects
New Transit Vehicles	Simplest way to carry more people.	Very expensive. Time lag up to 2 years. Capacity problem in crisis does not justify fleet expansion.
Larger Transit Vehicles	Can increase transit capacity while possibly reducing labor costs.	Very expensive. May not be cost effective. Time lag of up to 2 years. Little operating experience.
Exclusive Lane for HOVS	Works very well if existing buses are available and if very high demand corridor exists.	Not effective if no extra capacity is available. May be costly. Enforcement difficulties.
Use of Privately Owned Transit Vehicles	Expands capacity without expanding fleet. Buses generally compatible for transit service.	Availability of buses and cost of leasing unknown.
Use of school buses	Expands capacity without expanding fleet.	Conflicts with school needs likely. School buses not designed for transit use or for adults.
Storage and/or Rehabilitation of Older Buses	Reserve fleet provides considerable flexibility.	Needs to be done in advance of a crisis. Maintenance needs will be greater. Storage space needed.
Deferring Nonessential Maintenance	Can be done immediately. If time between nonessential maintenance checks is increased on the order of 25%, serious problems less likely. Effective in short run.	Negative effects (increased breakdowns and other maintenance problems) accumulated in lengthy crisis. Not feasible if spare ratio is already low.
Adjusting Routes and Schedules	Can increase system effectiveness.	Reduced service will bring opposition, particularly in crisis. Best done in non-crisis situation.
Instituting or Expanding Express Bus Service	Very effective if extra buses are available.	Need extra buses to implement. High cost.

TABLE 3.1 (Continued)

SUMMARY OF PEAK-HOUR CAPACITY - EXPANDING OPTIONS

Option	Positive Aspects	Negative Aspects
Instituting or Expanding Demand Responsive Services	Can help transit system meet increased demand.	Not energy-efficient. Administrative problems possible.
Changing Service Standards	Can be done immediately. No cost. Gives operator time to consider alternatives.	Quality of service lowered. May not be appropriate for long run.
Changing Marketing Practices	Supporting action	
Using Other TSM Techniques		Not likely to affect capacity.
Variable Work Hours	By shifting demand, increases peak capacity without cost to operator. Increases system effectiveness. Works best in dense downtowns with high concentration of public employees.	Implementation of large scale program can be difficult. Local factors important in determining success. Needs pre-crisis planning.
Peak/Off-Peak Fare Differential	Can raise revenue if peak fare increased. Fair for uses to pay more for peak service, which costs more to provide.	Best implemented in non-crisis. Flat fare system very popular due to its simplicity.

Table 3.2

SUMMARY OF TRANSIT OPERATORS' RESPONSES TO 1979 SHORTFALL

Action	No. of Systems Taking Action	% of Respondents[1]	No. of Systems Recommending Action	% of Respondents[1]	Average Effectiveness (1-4 scale, 4 highest)	Average Cost[2]
Relax informal operating standards	17	37.8%	1	2.2%	2.9	Low
Increase park & ride /express service	12	26.7	3	6.7	2.9	High
Bring retired buses out of storage	9	20.0	7	15.6	3.0	High
Variable work hours	9	20.0	7	15.6	2.1	None to Operator
Readjust maintenance practices	8	17.8	6	13.3	2.5	High
Reassign buses	3	6.7	6	13.3	2.7	N.A.
Turn back buses	3	6.7	5	11.1	2.7	Moderate
Speed up procurement	2	4.4	1	2.2	4.0	N.A.
Lease school buses	1	2.2	2	4.4	3.0	High
Initiate fare differential	0	0.0	6	13.3	--	--
Lease private buses	0	0.0	1	2.2	--	--

Most common problems: Insufficient financial resources
Union and personnel problems (shortage of qualified mechanics)
Maintenance problems

1. A total of 45 transit operators responded to our questions. See Appendices A,B,C,D.

2. Cost is defined as follows: Low - less than $100 per day
Moderate - $100 - $1000 per day
High - over $1000 per day

See Appendix D for more details.

that riders will not tolerate overcrowded conditions for long. Appendix D contains a fuller description of the responses of transit operators.

Tables 3.3 through 3.5 present packages of recommended actions for various crisis levels. The actions are presented within each package in the recommended order of implementation. These packages are designed to account for the fiscal capabilities of a transit system by suggesting low-cost actions along with supplementary high-cost options in the event that extra money becomes available. Of course, the operating characteristics of a given transit system may lead to different packages of options; for example, a system may already be operating with a low spare ratio, providing extensive express bus service, or maintaining stricter-than-average service standards. The recommendations in this section should certainly be modified to match the characteristics of an individual transit system.

Most of the low-cost recommendations lose their effectiveness quickly. This is particularly true of the package for a minor crisis because of its heavy reliance upon actions with sharply-diminishing returns. As a crisis situation continues or becomes more severe, there will be an increasing need for more operating funds. It has generally been assumed in the energy contingency literature that increased government subsidies will provide the needed financing. It is likely, however, that there will be increasing pressure for a fare increase. Only a scattering of systems reported fare increases during the 1979 crisis; from what evidence is available, fare increases tended to lower ridership to a point at which peak capacity problems were averted. It should be noted, however, that the preponderance of fare increases in 1980 may well have been a delayed reaction to the

Table 3.3

RECOMMENDATIONS FOR A MINOR PEAK-HOUR CAPACITY PROBLEM

BASIC PACKAGE:	
1. Adjust Service Standards	Return to the worksheet and recalculate Capacity Problem Index using new acceptable peak load factor. APL should not exceed 1.7. If crisis lasts for longer than 6-8 weeks, acceptable peak load should be modified if extremely crowded conditions prevail (APL $\geq$ 1.5).
2. Encourage Variable Work Hours	Lobby local officials to establish or improve a variable work hours program. Particularly appropriate in older cities with denser CBDs and where a concentration of public employees exists.
3. Change Marketing Practices	Orient toward providing information; there is a need for it. Supporting action.
4. Increase Peak/Off Peak Fare Differential	Implement if fare differential is already in effect and many routes have peak-hour capacity problems.
SUPPLEMENTARY PACKAGE:	
1. Defer Non-essential Maintenance	Monitor effects on condition of fleet and maintenance cost. Continue on a lesser scale after 6-8 weeks or if problems develop. Difficult if spare ratio is already low.
2. Activate Reserve Fleet	Monitor maintenance problems closely. Reserve fleet particularly useful if population is under 500,000.
3. Institute/Expand Express Bus and Park and Ride Service	Use reserve fleet. Most appropriate in smaller cities, where express bus service is presumably less common.

Table 3.4

RECOMMENDATIONS FOR A MODERATE PEAK-HOUR CAPACITY PROBLEM

BASIC PACKAGE:	
1. Adjust Service Standards	Return to the worksheet and recalculate Capacity Problem Index using new acceptable peak load factor. APL should not exceed 1.7. If crisis lasts 6-8 weeks, APL should be modified if extremely crowded conditions prevail (e.g., APL $\geq$ 1.5).
2. Consider Actions in Basic Package for Minor Problem	(See Table 3.3, preceding page).
3. Speed Up Bus Procurement	If possible
4. Adjust Routes and Schedules	
5. Institute Demand - Responsive Service	Use to replace conventional transit in outlying areas.
6. Defer Non-essential Maintenance	Monitor closely - continue on a lesser scale after 6-8 weeks or if maintenance cost rises. Difficult if spare ratio is already low.
SUPPLEMENTARY PACKAGE:	
1. Activate Reserve Fleet	Use with regular fleet. Reserve fleet particularly useful if population is under 500,000.
2. Lease Privately Owned Vehicles	
3. Institute/Expand Express Bus and Park and Ride Service	Use private vehicles. Most appropriate in smaller cities, where express bus service is presumably less common.
4. Encourage Establishment of HOV Lanes.	Lobby local officials.
5. Raise Fares	Additional revenue may be necessary.

Table 3.5

RECOMMENDATIONS FOR A SEVERE PEAK-HOUR CAPACITY PROBLEM

BASIC PACKAGE:	
1. Adjust Service Standards	Return to the worksheet and recalculate Capacity Problem Index using new acceptable peak load factor. APL should not exceed 1.7. If crisis lasts 6-8 weeks, modify APL if extremely crowded conditions prevail (e.g., APL $\geq$ 1.5).
2. Consider Actions in Basic Package for Moderate Problem	(See Table 3.4, preceding page)
3. Encourage 4 Day Work Week	Lobby local officials.
4. Activate Reserve Fleet	Use with regular fleet. Reserve fleet useful if population is under 500,000.
5. Lease Privately Owned Vehicles	Use for express service.
6. Lease School Buses	Use for express service or for shuttle service.
7. Institute/Expand Express Bus and Park and Ride Service	Use private and school buses. Most appropriate in smaller cities, where express bus service is presumably less common.
8. Encourage Establishment of HOV Lanes	Lobby local officials.
9. Raise Fares	New source of funds a virtual necessity. Fare increase not necessary if subsidies can be obtained. Implementation of peak/off peak fare differential also a possibility.
SUPPLEMENTARY PACKAGE:	
1. Purchase New Buses	Purchase of buses a last resort due to time lag before they arrive. In extremely severe crisis, or in seemingly long-term crisis, may be justified.
2. Purchase Larger Buses	

increase in transit operating costs resulting from the 1979 crisis. A fare increase is not a desirable option, but it is preferable to a general cut in service. In a severe energy shortfall, the price of fuel is likely to rise sharply, thus increasing the operator's costs and intensifying the need for additional funding. While even an increased transit fare may be seen as a bargain in comparison with skyrocketing gasoline prices, the irony of the situation is that the result of inadequate levels of public funding of transit becomes apparent at precisely the time when transit services are most needed.

The recommendations for the various packages hold for all types of cities, with some modifications noted in the tables. Transit operators in older cities with densely-developed CBDs or in cities with a high concentration of public-sector employment can benefit most from a variable work hours program and should aggressively pursue its establishment by lobbying local officials. Since transit systems in urbanized areas with population less than 500,000 tend to operate with little or no margin in terms of spare ratio, operators in such systems should consider more closely the establishment of a small reserve fleet. There may also be a greater possibility for expansion of express bus service in smaller urbanized areas. Beyond these generalizations and any unique characteristics of a given transit system, the packages apply to United States transit systems regardless of city size, system size or geographical location.

The first recommendation in each basic package is to adjust service standards by changing the acceptable peak load factor. This is most useful where relatively strict service standards are being maintained. APL values

of 1.7 have been suggested for a crisis (28), and an APL factor of 1.5 is certainly acceptable in a crisis. Recall that this was the action most often taken in 1979 (Table 3.2). Changing the APL factor to allow more crowded buses also provides the transit operator with additional time to monitor the crisis and to take the necessary steps toward implementation of other actions.

The range of systemwide capacity increases is listed for all actions in Table 3.6. These numbers are obtained from survey responses of transit operators and give some idea of the magnitude of benefits associated with each action. Note that these are not route-specific numbers. Since only a small number of operators had detailed information on percentage capacity increase, ranges instead of averages are presented. Appendix D contains more details.

The basic package for a minor problem (Table 3.3) contains little beyond adjusting service standards that will have an immediate effect on peak-hour capacity. While actions in the supplementary package are more costly, the operator may choose to defer nonessential maintenance on a small scale (e.g., a moderate increase in the time between routine maintenance checks) or to activate a portion of the reserve fleet. By taking these supplementary actions on a small scale, the operator can probably hold costs to an acceptably low level.

For a moderate problem, the basic package in Table 3.4 considers additional actions which may be more costly (deferring non-essential maintenance, instituting demand-responsive service) or more difficult administratively

Table 3.6

RANGE OF SYSTEMWIDE CAPACITY INCREASES ASSOCIATED WITH ACTIONS

Action	Range of Systemwide Capacity Increase
Adjust Service Standards	Not applicable; changes APL, does not increase capacity per se.
Encourage Variable Work Hours	0-18%
Change Marketing Practices	0%
Increase Peak/Off-Peak Fare Differential	Unknown
Defer Non-essential Maintenance	1-10%
Activate Reserve Fleet	1-10%
Institute/Expand Express Bus and Park and Ride Service	2-30%
Speed up Bus Procurement	Approximately 15%, depends on number of buses.
Adjust Routes and Schedules	Approximately 4%
Institute Demand Responsive Service	Unknown
Lease Privately-Owned Vehicles	Unknown, depends on number and size of vehicles.
Encourage Establishment of HOV Lanes	Unknown
Raise Fares	Unknown
Lease School Buses	Unknown, depends on number and size of buses.
Purchase New Buses	Depends on number and size of buses.
Purchase Larger Buses	Depends on number and size of buses.

(demand-responsive service, adjusting routes and schedules, speeding up bus procurement). The basic package for a severe problem contains all of the short-term options, and includes a provision for raising fares. Raising fares is treated in this analysis as an option to be avoided whenever possible, but it is a supplementary action for a moderate problem and must be considered during a severe peak-hour capacity problem.

Actions are listed in all the tables in the suggested order, but depending upon the characteristics of an individual transit system, the operator may wish to rearrange this order.

The tables of recommendations included in this section may be used in conjunction with the Capacity Problem Index of the preceding section to provide a transit operator with a program of actions appropriate for the system in question. These packages of recommended actions have been developed primarily from information on actions actually taken by transit operators in 1979 and secondarily from reviews of the transit literature and of energy contingency plans. Use of the CPI and these tables allows a transit operator to plan in advance for various energy scenarios and to react immediately to an unexpected crisis.

4. SUMMARY AND CONCLUSIONS

At a time when transit systems nationwide are facing a drastic decline in operating subsidies and are making difficult decisions regarding fare and service levels, a study of peak-hour capacity-expanding options may seem to be a remote undertaking. However, like fiscal crises, energy crises are likely to occur at unpredictable times in the future. By knowing the effectiveness of actions taken in past crises and by making plans for future energy scenarios, a transit operator can be better prepared to cope with an emergency situation.

This study has presented guidelines for transit operators facing peak-hour capacity problems triggered by an energy crisis. A simple two-step process has been described which tells transit operators when a given route or set of routes will experience a peak-hour capacity problem and what actions to take to alleviate the problem. The Capacity Problem Index described in Section 2 requires only the current and acceptable peak load factors and the proportion of ridership carried in the peak hour. The worksheet for calculating the CPI leads the user to the appropriate package of recommended actions in Section 3. The CPI can be used in advance of a crisis as part of the contingency planning process, or it can be used during a crisis. With the simplicity and flexibility of the process involving the index and the tables of recommendations, the transit operator gains a valuable tool for assessing and addressing future energy shortfalls.

Several conclusions arise from the process of developing the index and recommendations:

(1) The best action to take first in a crisis is to change service standards. Allowing more crowded buses gives the transit operator additional time to monitor the energy situation, to finalize plans for action and to do any necessary pre-implementation work (e.g., prepare a reserve fleet for service). This was the action most often taken by transit operators in 1979. It can be implemented immediately, and it costs nothing.

(2) There is a balance to be drawn between the cost of an action and its benefits. Stated otherwise, actions which have the greatest effect on capacity also tend to have the highest cost. The money available to a transit operator will determine whether only the basic package is selected or actions from the supplementary package are also included.

(3) The important time frame for determining peak-period capacity problems is the peak-hour. Longer time frames are too broad to pinpoint problems. Shorter periods of time are often used, and the worksheet can accommodate these shorter periods. The examples are worked out with peak-hour data.

(4) The responses of transit operators in 1979 indicated that most actions are applicable to any transit system regardless of location or size. However, some actions are more or less effective under certain circumstances:

- changing operating standards is most effective where existing standards are stringent;

- park-and-ride and express bus service is most effective in smaller cities where such service is presumably less common (large cities may be saturated with such service);
- deferring non-essential maintenance is difficult in cities where the spare ratio is low;
- a small reserve fleet may be most useful in cities under 500,000, where spare ratios tend to be low;
- a variable work hours program in most appropriate in older cities with denser CBDs, or in cities where there is a high concentration of public employment.

(5) Actions which can be taken immediately often lose their effectiveness quickly. The public is not likely to tolerate for long crowded conditions brought on by a change in service standards. Deferring non-essential maintenance and activating a reserve fleet composed of older buses may quickly produce more breakdowns rather than provide more buses. A time frame of 6-8 weeks is suggested as optimal for these actions. Within this period of time, performance should be monitored especially carefully and other actions readied for implementation.

(6) Major changes in routing and fare structures are <u>not</u> recommended. There will be enough confusion due to the crisis itself. If the peak-hour capacity problem is severe, some changes of this nature may be necessary. Generally, however, a crisis is no time for major changes on basic elements of the transit system.

(7) A severe peak-hour capacity problem may necessitate a fare increase. This can be a peak-hour surcharge or a general increase. Increased revenue is required to finance necessary

options in a severe crisis. A fare increase will also dampen demand. Operators who raised fares in 1979 reported no peak-hour capacity problems, but were hardly acting in the public interest in taking such an action at that time.

(8) Cooperation with local officials is necessary for the implementation of several actions. Positive working relationships in everyday situations pave the way for crisis cooperation.

This report is designed for use as a manual by transit operators. The text of the report is streamlined for easier use, while supporting documentation may be found in the appendices. Appendix D contains a fuller analysis of the responses of transit operators to the 1979 energy shortfall. Appendix E discusses and evaluates each of the capacity-expanding options in detail. Appendix F presents the derivation of the Capacity Problem Index. Along with providing greater detail on many issues related to expanding peak-hour transit capacity, the appendices should provide useful sources of information to those wishing to find out more about a particular issue or option. For example, Appendix D summarizes where the 1979 shortfall had the greatest and least impacts on peak-hour transit capacity, while Appendix E contains several examples of the implementation of capacity-expanding options and their effectiveness. Of course, the study as a manual is designed for use without reference to the appendices.

Certain general issues must be kept in mind in planning actions to combat a peak-hour capacity problem. Among those discussed in Section 1, the most problematic are additional personnel and fuel supply. Transit operators

indicated widespread dissatisfaction with personnel hired during the 1979 crisis. Training programs need to be improved and made more flexible in order to be able to cope with a possible flood of trainees. A key to the solution may be with the part-time use of retired personnel in training programs. Regarding fuel supply, federal regulations governing a guaranteed fuel supply for transit in a crisis situation have been rescinded. Transit operators need to make their own arrangements to ensure adequate fuel supplies in a crisis. Additional storage tanks or long-term guaranteed contracts with fuel suppliers are two possible actions. Even if nothing else is done in preparation for a future crisis, these two issues should at least be acknowledged by transit operators.

Using the worksheet for the Capacity Problem Index, an operator can quickly determine whether capacity problems exist or are likely to occur on key routes in the transit system. The worksheet leads the operator by use of tabs to the package of recommended actions appropriate for the degree of severity of the peak-hour capacity problem. The operator can then implement the actions in the indicated order, or can select actions most appropriate for the circumstances and the system. This report, in summary, provides a simple, rapid method for anticipating and/or reacting to a peak-hour capacity problem. Additionally, the appendices synthesize available information on capacity-expanding options and on operators' responses to the 1979 shortfall. In this way, an easy-to-use manual has been combined with detailed information in a single report, which provides the means for a transit operator to assess the situation, choose appropriate actions, and justify his decisions.

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NEW YORK STATE DEPARTMENT OF TRANSPORTATION
SURVEY OF ACTIONS TO INCREASE TRANSIT
CAPACITY DURING THE 1979 GASOLINE SHORTAGE

October 1981

City _____ Transit Operator _____

1. Did the 1979 gasoline shortage create or worsen peak-period capacity problems on your transit system? Yes ____ No ____

2. The following is a list of options to increase transit capacity in the perk-period. Please check any actions actually taken during the 1979 gasoline shortage in Column A.

   Please rate the overall effectiveness of any action taken in Column B on a scale of 1-4, where:

   4 = very effective (most capacity problems solved)
   3 = effective (general improvement noted, problem partially alleviated)
   2 = minor or no effect (problem not alleviated)
   1 = ineffective (other problems created)

   Please also indicate the approximate increase in daily peak-period seat capacity in Column C and the approximate dollar cost in Column D resulting from any action taken.

	Column A Implemented	Column B Effectiveness	Column C Daily Peak-Period Seat Capacity Increase	Column D Daily Cost
Bring "retired" buses out of storage	_____	_____	_____	_____
Readjust maintenance practices to reduce spare ratio in peak-period	_____	_____	_____	_____
Turn back buses at intermediate points along high density corridors	_____	_____	_____	_____
Reassign buses from low-demand to high-demand routes	_____	_____	_____	_____
Lease or share school buses	_____	_____	_____	_____
Lease or share privately owned buses	_____	_____	_____	_____
Increase park and ride/ express bus services	_____	_____	_____	_____
Relax informal operating standards (i.e., allow more crowded buses)	_____	_____	_____	_____
Speed up procurement process for new buses on order	_____	_____	_____	_____
Initiate peak/off-peak fare differential	_____	_____	_____	_____
Other (explain below)	_____	_____	_____	_____

_____

_____

3A. Did any major employer in your service area change to staggered work hours during the 1979 energy shortage? Yes ____ No ____

3B. If so, please rate the effectiveness of the work hour change on peak-period capacity on routes or terminals serving the employer (Use the 1-4 scale described in Question 2) _____

3C. If possible, please estimate percentage change in peak-period transit demand for affected routes. _____

4. Please describe briefly any problems which arose in implementing actions to increase transit capacity.

_____

_____

5. Were there any actions considered for implementation in 1979 but not acted upon? Please describe briefly the problems concerning these actions.

_____

_____

6. Based upon your experiences during the 1979 gasoline shortage, what actions would you recommend for a future situation of this nature? Please feel free to indicate any other measures currently being planned which, due to lead-time requirements, were not implemented in 1979.

_____

_____

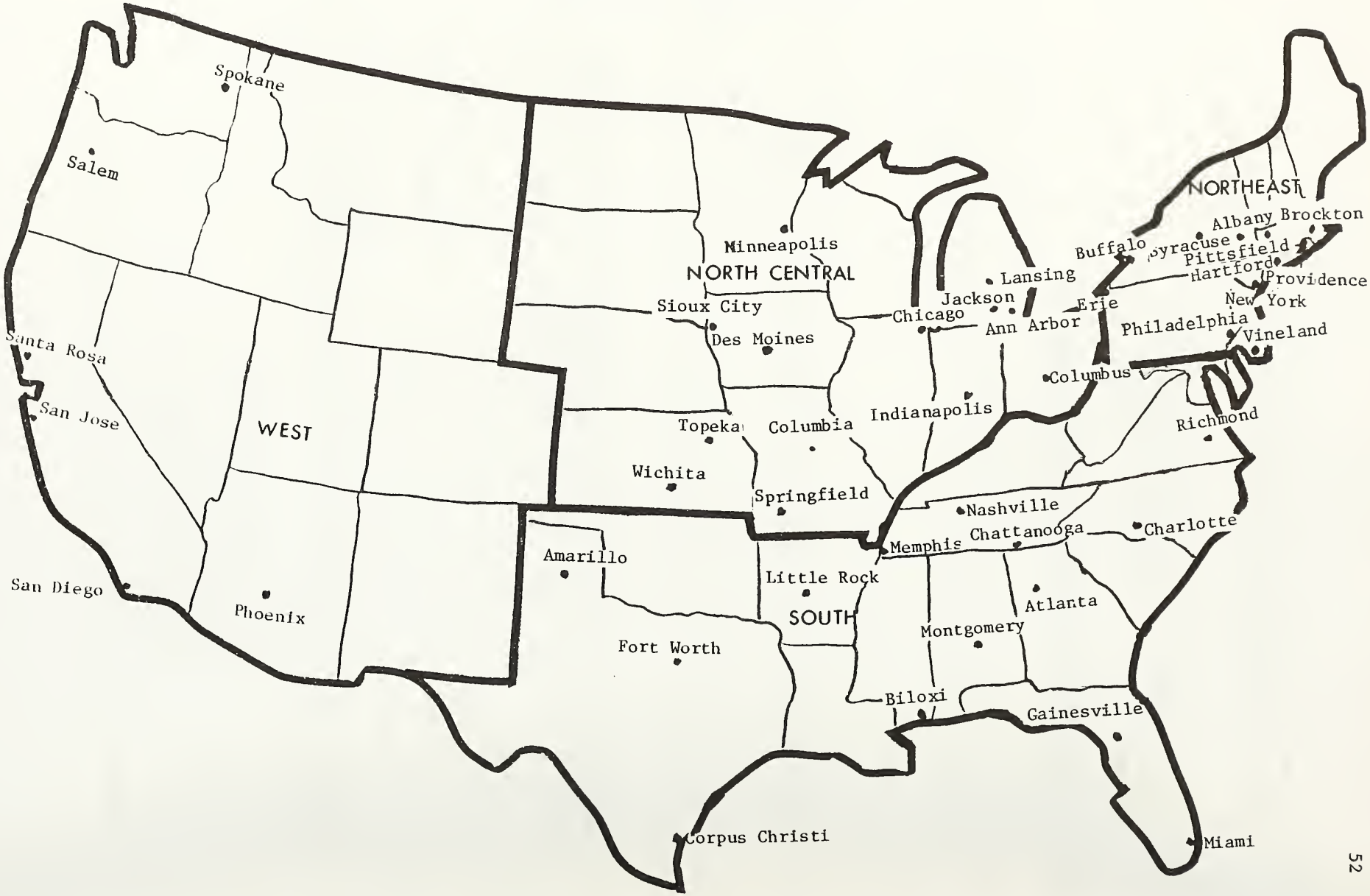
_____

Thank you for answering these questions. We will send you a copy of the study when it is completed. Please return the questionnaire in the enclosed postage paid envelope to:

New York State Department
of Transportation
Building 4, Room 108
1220 Washington Avenue
Albany, New York 12203

If there are any problems, call Dan Boyle at (518) 457-2967.

APPENDIX D: GEOGRAPHIC REGIONS



APPENDIX C

SAMPLE URBANIZED AREAS

Albany, N.Y.
Amarillo, TX
Ann Arbor, MI
Atlanta, GA
Biloxi-Gulfport, MS
Brockton, MA
Buffalo, NY
Charlotte, NC
Chattanooga, TN
Chicago, IL
Columbia, MO
Columbus, OH
Corpus Christi, TX
Des Moines, IA
Erie, PA
Fort Worth, TX
Gainesville, FL
Hartford, CT
Indianapolis, IN
Jackson, MI
Lansing, MI
Little Rock, AK
Memphis, TN
Miami, FL
Minneapolis, MN
Montgomery, AL
Nashville, TN
New York, NY - MSBA only
Philadelphia, PA - SEPTA and PATCO
Phoenix, AZ
Pittsfield, MA
Providence, RI
Richmond, VA
Salem, OR
San Diego, CA
San Jose, CA
Santa Rosa, CA
Sioux City, IA
Spokane, WA
Springfield, MO
Syracuse, NY
Topeka, KS
Vineland-Millville, NJ
Wichita, KS

APPENDIX D

Transit Operators, 1979: The Survey

In order to obtain more information on capacity-related problems and the effectiveness and cost of options, a short survey was prepared and mailed to approximately 100 transit operators nationwide. The survey was designed to determine the extent to which there were peak-period capacity problems during the 1979 energy shortfall. Operators were also questioned as to the effectiveness and cost of actions implemented in 1979, problems encountered, and recommendations for future crises. A copy of the survey may be found in Appendix A.

A sample of 68 transit operators in 66 urbanized areas, used in a previous study on transit ridership changes during the 1979 energy shortfall (4), was augmented with 34 other systems chosen by stratified random sampling techniques to yield an overall sample representative with respect to urbanized area size and system location. Where appropriate in very large cities, more than one operator was surveyed. Of the 102 surveys distributed, a total of 45 responses from 44 urbanized areas were received. Appendix B indicates the location of urbanized areas included in the sample, while Appendix C provides a list of the urbanized areas. Tables D.1 and D.2 show response rates broken down by region and size. It may be seen that the lowest reponse rates were among systems in very small urbanized areas, while systems in very large and medium-sized urbanized areas had the best response rates. Consequently, systems in urbanized areas over 250,000 population are

Table D.1

RESPONSE RATES OF TRANSIT OPERATORS BY URBANIZED AREA SIZE

Population Size	No. of Urbanized Areas in U.S. With Transit		No. of Surveys Sent		No. of Surveys Received		Response Rate (%)
Very Large (Over 1,000,000)	25	9.6%	14	13.7%	10	22.2%	71.4
Large (500,000-1,000,000)	21	8.1%	12	11.8%	6	13.3%	50.0
Medium (250,000-500,000)	35	13.5%	12	11.8%	8	17.8%	66.7
Small (100,000-250,000)	96	36.9%	34	33.3%	13	28.9%	38.2
Very Small (50,000-100,000)	83	31.9%	30	29.4%	8	17.8%	26.7
Total	260	100.0%	102	100.0%	45	100.0%	44.1

Source: Urban Mass Transportation Administration (42)

Table D.2

RESPONSE RATES OF TRANSIT OPERATORS BY REGION

Region [1]	No. of Urbanized Areas in U.S. With Transit [2]		No. of Surveys Sent		No. of Surveys Received		Response Rate (%)
Northeast	52	20.0%	22	21.6%	12	26.7%	54.5
South	93	35.8%	36	35.3%	14	31.1%	38.9
North Central	74	28.5%	28	27.5%	13	28.9%	46.4
West	41	15.8%	16	15.7%	6	13.3%	37.5
Total	260	100.0%	102	100.0%	45	100.0%	44.1

1. Region definitions based on U.S. Census divisions; see Appendix B.

2. Source: Urban Mass Transportation Administration (42)

somewhat overrepresented in this sample while systems in smaller urbanized areas are underrepresented.

Peak Capacity Problems

The results of the survey indicate that the 1979 energy crisis did worsen peak-period transit capacity problems among certain systems. Table D.3 presents these results. Systems in medium-sized urbanized areas consistently reported capacity problems while systems in smaller urbanized areas generally did not experience problems. If a division is made at a population of 250,000, 74% of systems in urbanized areas over 250,000 population experienced a worsening of peak capacity problems while only 33% of systems in small urbanized areas reported such problems. In every region, systems in larger urbanized areas experienced more problems than systems in smaller urbanized areas. The Northeast reported the most problems while the South had the least.

The conclusions to be drawn are that systems in small and very small urbanized areas and Southern systems did not generally experience capacity problems in 1979. These problems were most prevalent on systems in urbanized areas with over 250,000 population and on systems in the Northeast.

These conclusions contrast with previous work concerning transit capacity (41). This previous study indicated that very large and very small systems would be least able to cope with capacity problems brought on by an energy crisis and that systems in the Northeast and South would not have the excess

Table D.3

NUMBER OF SYSTEMS REPORTING PEAK-PERIOD CAPACITY PROBLEMS AS A RESULT OF 1979 ENERGY CRISIS

Urbanized Area Size	Region									
	Northeast		South		North Central		West		All Regions	
	Prob.	No Prob.	Prob.	No Prob.	Prob.	No Prob.	Prob.	No Prob.	Prob.	No Prob.
Over 1,000,000	3	1	1	1	1	1	2	0	7	3
500,000-1,000,000	0	1	1	1	2	0	1	0	4	2
250,000- 500,000	3	0	2	1	2	0	0	0	7	1
100,000-250,000	1	1	1	5	2	2	1	0	5	8
50,000-100,000	2	0	0	1	0	3	0	2	2	6
All Systems	9	3	5	9	7	6	4	2	25	20

See Appendix B for boundaries of regions.

capacity available to handle increased demand in a crisis. The results here show that systems in very small urbanized areas and Southern systems experienced few capacity-related problems in 1979 and that not only very large systems but systems in urbanized areas over 250,000 (medium to very large) did have problems. Both these results and the previous study agree on the extent of capacity-related problems in the Northeast.

Actions Taken in 1979

The survey form listed 10 possible capacity-expanding actions and asked operators to indicate if the action was taken, to rank its effectiveness on a 1 to 4 scale, and to estimate actual daily capacity increase and actual daily cost. A separate set of questions elicited similar information on variable work hours; since the cost of this action is generally not borne by the operator, the cost question was omitted for variable work hours. Tables D.4 through D.7 present the results of this part of the survey. Table D.4 looks at the frequency of implementation, effectiveness and cost while Tables D.5 through D.7 provide a breakdown of actions taken by system size and region. Regional differences were not pronounced. Systems in very small urbanized areas took few actions, since they generally reported no problems. Interestingly, systems in very large urbanized areas rarely increased park-and-ride or express services; presumably, these systems already operated fully-developed park-and-ride/express service.

From Table D.4 it may be seen that relaxing informal operating standards, increasing park-and-ride or express service, bringing retired buses back into service, readjusting maintenance practices, and encouraging variable

Table D.4

NUMBER, EFFECTIVENESS AND COST OF ACTIONS TAKEN IN 1979

Action	No. of Systems Taking Action	% of Respondent	Effectiveness (1-4 scale)		Percentage Capacity Increase			Daily Cost ($)		
			Range	Average	η	Range	Average	η	Range	Average
Relax informal operating standards	17	37.8	1-4	2.9	7	0-27	9.6	6	0-300	50
Increase park and ride/express service	12	26.7	2-4	2.9	5	2-30	10.4	3	800-7,000	4,267
Bring retired buses out of storage	9	20.0	2-4	3.0	6	1-10	5.2	4	100-3,000	1,243
Variable work hours	9	20.0	1-3	2.1	5	0-18	7.6	No costs assumed		
Readjust maintenance practices	8	17.8	1-3	2.5	6	1-10	5.0	4	40-5,000	1,710
Reassign buses	3	6.7	2-4	2.7	0	-	NA	0	-	NA
Turn back buses	3	6.7	2-3	2.7	1	-	4.0	1	-	240
Speed up procurement	2	4.4	-	4.0	1	-	15.0	0	-	NA
Lease school buses	1	2.2	-	3.0	1	-	3.0	1	-	2,860
Initiate fare differential	0	0	-	2.0 (est)	0	-	-	0	-	-
Lease private buses	0	0	-	1.0 (est)	0	-	-	0	-	-

Table D.5

NUMBER OF SYSTEMS TAKING SPECIFIC ACTIONS IN 1979
(AND AVERAGE OF EFFECTIVENESS RATINGS) BY SIZE OF URBANIZED AREA

	URBANIZED AREA SIZE					
Action	Over 1,000,000	500,000-1,000-000	250,000-500,000	100,000-250,000	50,000-100,000	All Systems
Bring retired buses out of storage	3 (3.0)	1 (4.0)	3 (3.0)	1 (3.0)	1 (2.0)	9 (3.0)
Readjust maintenance practices	3 (2.3)	1 (3.0)	2 (3.0)	2 (2.0)	-	8 (2.5)
Turn back buses	2 (2.5)	-	1 (3.0)	-	-	3 (2.7)
Reassign buses	2 (2.0)	-	-	1 (4.0)	-	3 (2.7)
Lease school buses	1 (3.0)	-	-	-	-	1 (3.0)
Lease private buses	-	-	0 (1.0)*	-	-	0 (1.0)*
Increase park-and-ride/express service	2 (3.0)	3 (2.7)	3 (3.0)	4 (3.0)	-	12 (2.9)
Relax informal operating standards	6 (2.5)	2 (2.5)	5 (3.5)	4 (3.3)	-	17 (2.9)
Speed up bus procurement	-	2 (4.0)	-	-	-	2 (4.0)
Initiate fare differential	-	-	0 (2.0)*	-	-	0 (2.0)*
Variable work hours	1 (3.0)	2 (1.5)	4 (2.3)	2 (2.0)	-	9 (2.1)

Effectiveness is measured on a scale of 1-4, with 1 being ineffective and 4 being very effective. For more details see survey form in Appendix A.

*Estimated effectiveness - action not taken

Table D.6

NUMBER OF SYSTEMS TAKING SPECIFIC ACTIONS IN 1979
(AND AVERAGE OF EFFECTIVENESS RATINGS) BY GEOGRAPHICAL REGION

Action	Region: Northeast	South	North Central	West	All Systems
Bring retired buses out of storage	3 (3.5)	2 (2.0)	4 (3.0)	-	9 (3.0)
Readjust maintenance practices	2 (2.5)	3 (2.7)	2 (2.0)	1 (3.0)	8 (2.5)
Turn back buses	2 (3.0)	-	1 (2.0)	-	3 (2.7)
Reassign buses	-	-	2 (3.0)	1 (2.0)	3 (2.7)
Lease school buses	-	1 (3.0)	-	-	1 (3.0)
Lease private buses	-	-	0 (1.0)*	-	0 (1.0)*
Increase park-and-ride /express bus service	2 (3.0)	3 (3.0)	5 (3.0)	2 (2.5)	12 (2.9)
Relax informal operating standards	6 (2.6)	4 (3.0)	4 (3.0)	3 (3.3)	17 (2.9)
Speed up bus procurement	-	-	1 (4.0)	1 (4.0)	2 (4.0)
Initiate fare differential	-	-	0 (2.0)*	-	0 (2.0)*
Variable work hours	1 (3.0)	1 (2.0)	4 (1.8)	3 (2.3)	9 (2.1)

Effectiveness is measured on a scale of 1 to 4, with 1 being ineffective and 4 being very effective. For more details, see survey form in Appendix A.

*Estimated effectiveness - action not taken

Table D.7

PERCENTAGE INCREASE IN PEAK-PERIOD CAPACITY AND DAILY COST ASSOCIATED WITH CAPACITY EXPANDING OPTIONS

Bring Retired Buses out of Storage

	% Capacity	Cost
VL NE	6	NA
VL NC	5	NA
M NE	1	270
M NE	6	1600
M NC	10	3000
VS S	3	100
Avg.	5.2	1243

Readjust Maintenance

	% Capacity	Cost
VL NE	1	40
VL S	1	600
L W	10	NA
M S	6	NA
M NC	5	1200
S S	7	5000
Avg.	5	1710

Turn Back Buses

	% Capacity	Cost
VL NE	4	240

Lease School Buses

	% Capacity	Cost
VL S	3	2860

Increase Park-and-Ride/Express Bus Service

	% Capacity	Cost
L W	3	NA
M NE	2	800
M S	10	NA
M NC	30	7000
S S	7	5000
Avg.	10.4	4267

Relax Informal Operating Standards

	% Capacity	Cost
VL S	NA	0
VL W	NA	0
L W	10	NA
M NE	0	0
M S	10	NA
M S	0	0
M NC	10	300
S NE	10	0
S W	27	NA
Avg.	9.6	50

Variable Work Hours

	% Capacity
L NC	0
L W	5
M NE	18
M NC	10
M NC	5
Avg.	7.6

Speed Up Procurement

	% Capacity	Cost
L W	15	NA

Systems are defined by urbanized area size and by region. See Table D.1 for definitions of urbanized area size and Appendix B for map of regions.

Where capacity increase was not given as a percentage but as a number of additional seats, 45 seats per bus were assumed and peak-hour vehicle requirement (42) used to compute base.

work hours programs were most often implemented in 1979. Other actions were rarely taken.

Table D.4 also presents the averages and ranges of effectiveness (rated on a 1 to 4 scale; see Appendix A), percent capacity increase and daily cost. In answering the survey, some operators gave an absolute increase in seat capacity; this was converted to a percentage increase by finding the peak hour vehicle requirement for the system (42, early 1980 was the closest date on which the information was available) and assuming 45 seats per bus. It must be noted that many operators were unable to provide figures on capacity increase and cost. Table D.4 indicates the number of responses from which average percentage increases and costs were computed.

Relaxing informal operating standards (basically a "do-nothing" option) was generally effective at low cost, although it seemed less effective in the Northeast and in large and very large urbanized areas. Increasing park-and-ride/express service was also generally effective, but at a very high cost. Bringing retired buses back into service was moderately effective with a high cost. Readjusting maintenance practices resulted in low benefits and high costs. Variable work hours were ranked low on the effectiveness scale but seemed to produce moderate shifts in demand out of the peak. Among actions rarely taken, speeding up the procurement of buses resulted in very high benefits, but only two systems were able to do this in 1979. Similarly, only one system attempted the use of school buses and reported significant costs.

Implementation Problems

Several problems arose when transit operators attempted to implement capacity-increasing actions. Financial considerations were emphasized in the operators' comments: either there was no working capital available or the marginal cost of the option exceeded the marginal revenue. Personnel and union problems were also prevalent. New personnel hired during the crisis was often reported unsatisfactory. A shortage of qualified mechanics was noted, and drivers' unions occasionally objected to certain actions. Small operators generally put as many vehicles as possible into service as a standard practice and so were particularly vulnerable to peak capacity problems in a crisis. Some large operators experienced serious problems with the physical condition of the existing fleet, and so were saddled with high spare ratios. These were the major problems noted, along with obvious concerns as to fuel and fleet storage and fuel supply.

One operator indicated that while several actions were taken during 1979, there were no long-term solutions among the options. This may be because no way has yet been found to reduce the inefficiencies inherent in the operation of transit systems with such pronounced peaking characteristics. In this view, crises do not cause capacity problems; they only magnify the severity of the existing problems.

Unique circumstances sometimes prevented the worsening of peak capacity problems. One system reported no true peak period while another said its peak was unrelated to work travel. A series of fare increases counter-balanced the increased demand resulting from the energy shortfall on one system. Finally, a system near the Canadian border reported little shift to

transit as motorists found low prices and plentiful gasoline across the border.

In general, implementation problems most frequently involved finance, maintenance, and personnel. The most common reasons for not implementing proposed actions were financial barriers and long lead times.

Operator Recommendations

Transit operators were asked to recommend actions to be taken in a future crisis situation based upon their experiences in 1979. Table D.8 ranks actions by frequency of recommendations and compares the number of times an action is recommended with the number of times it was actually implemented in 1979. Reassigning buses and initiating a peak/off-peak fare differential were recommended significantly more often than they were actually taken. The time frame and a lack of preparation may explain why a fare differential was not instituted more often. Small scale actions related to operations, such as reassigning buses, may be more appealing given the current fiscal state of transit. Variable work hours, ranked fifth among actions taken, is most often recommended. Again, operators may feel that now there is time to develop a variable work hours program.

The most dramatic differences between actions taken and actions recommended involve increasing park-and-ride/express service and relaxing informal operating standards; both were taken in 1979 far more often then they were recommended for a future crisis. This is puzzling at first glance, because Table D.4 indicated tht both actions were rated as moderately effective.

Table D.8

ACTIONS RECOMMENDED FOR FUTURE CRISES

Action	No. of Systems Recommending Action	No. of Systems Taking Action in 1979
Variable work hours	7	9
Bring retired buses out of storage	7	9
Readjust maintenance practices	6	8
Reassign buses	6	3
Initiate fare differential	6	0
Turn back buses	5	3
Increase park-and-ride/ express service	3	12
Lease school buses	2	1
Relax informal operating standards	1	17
Speed up procurement	1	2
Lease private buses	1	0

However, increasing park-and-ride/express services was the most expensive action; the cost may well have discouraged operators from recommending it. Relaxing informal operating standards is a default option, taken if nothing else is done. While operators may have been forced to relax operating standards in 1979 because of a lack of preparedness, financial difficulties, or other reasons, their reluctance to recommend it indicates an awareness that riders will not tolerate overcrowded conditions for very long. The list of recommendations in Table D.8 also indicates the most desirable actions in the absence of time constraints, since the recommendations presume that necessary preparations can be made.

Summary of Survey Results

A majority of systems in the sample reported that peak-hour capacity problems were created or worsened during the 1979 energy crisis. Systems in the Northeast were most affected, while systems in the South reported few problems. Systems in urbanized areas with a population over 250,000 experienced more problems than did systems in small urbanized areas. Actions most often taken are listed in Table D.9 along with their general effectiveness and cost. It should be noted that, despite its favorable ratings in Table D.9, relaxing operating standards was rarely recommended; presumably the decrease in quality of service resulting from this option is considered tolerable only in the short term.

Implementation problems most often concerned finance, maintenance, personnel and time requirements. No consensus emerged regarding recommendations.

Table D.9

SUMMARY OF ACTIONS MOST OFTEN TAKEN IN 1979

Action	Benefits	Cost
Relax informal operating standards	HIGH	LOW
Increase park-and-ride/express service	HIGH	HIGH
Bring retired buses out of storage	MODERATE	HIGH
Readjust maintenance practices	LOW	HIGH
Encourage variable work hours	LOW	NONE for operator

The survey results provide information derived from the experience of transit operators in 1979 concerning two factors of interest: the effectiveness of various capacity-increasing options, and the distribution of capacity problems. The recommendations for the various packages in Section 3 are based on the effectiveness of the 1979 actions, while the distribution of peak-hour capacity problems in 1979 indicates the extent to which the energy shortfall had a measurable effect on transit.

APPENDIX E

Increasing Peak-Hour Transit Capacity: Options and Evaluation

Reviews of the transit literature and of energy contingency plans reveal many different ways in which transit capacity may be increased. Actions discussed in this appendix are considered relevant to transit capacity, although some serve other purposes as well. Each option is defined in terms of its approach to the problem, cost to implement, feasibility, timeliness, and usefulness in different situations. A thorough evaluation of each option is also included in the discussion. Where possible, practical results and theoretical considerations are both incorporated into the analysis.

Options are grouped according to the general approach taken to the problem. There are three general approaches:

- fleet/roadway expansion involves an increase in the number or size of vehicles in the transit fleet or a change in the highway infrastructure which increases the roadway capacity for transit vehicles;
- change in operations involves procedural actions which increase capacity without capital expenditures for new equipment;
- shift in demand involves actions which, rather than increase the number of spaces available, seek to decrease the demand/space capacity ratio in peak hour by shifting some of the demand to the off-peak.

Table E.1 evaluates the differences among these approaches.

Table E.1

APPROACHES TO PEAK-HOUR CAPACITY PROBLEMS

	Approaches		
	Fleet/Roadway Expansion	Change in Operations	Shift in Demand
Time Frame	Long-term; considerable lead-time required	Short term; some actions can be implemented immediately	Medium; pre-planning required
Cost	High	Low to Moderate	Low to Moderate
Flexibility	Depends on Action	Reversible	Reversible
Targeted to Peak?	No	Yes	Yes
Under Whose Control?	Operator and local officials	Operator (generally)	Outside agencies/ Transit operator
Feasibility: Political	High	High	High
Fiscal	Low	High	Moderate to High
Technical/ Administrative	High	High	Low to Moderate
Appropriate for What Type of Crisis?	Severe	Minor	Moderate
Practical Effectiveness	Low in short run High in long run	Moderate to High	Questionable

Table E.2 summarizes the evaluation of peak-hour capacity-increasing options for transit systems. Most of the criteria are self-explanatory, but a few deserve explanation. Information from the literature and the survey is used to quantify the time frame and the cost of options where possible. The "control" of the options refers to the agencies or officials at the local level whose approval is necessary for implementation. Political feasibility is a measure of the acceptability of an option with various user groups; it is presumed that a measure adversely affecting one or more of these user groups would lead to political action attempting to halt implementation. As such, political and fiscal feasibilities are separated here to a greater extent than in the real world, where fiscal feasibility has a significant influence on political feasibility. An option deemed appropriate for a less serious crisis might also be taken in a more serious situation; the degree of severity in Table E.2 under "Appropriate for What Type of Crisis?" indicates the point at which an option might first be considered. A 0 to 10% shortfall is considered a minor crisis; 10 to 20% is a moderate crisis; over 20% is a severe crisis. "Practical effectiveness" refers to the ability of the option to increase peak-period transit capacity in a relatively brief period of time. The comments generally amplify upon the evaluation of effectivenss. The remainder of this appendix discusses and evaluates each option in more detail. As mentioned earlier, the options are grouped according to the general approach taken.

Fleet/Roadway Expansion

Actions in this category involve the acquisition of more or bigger buses or of more roadway capacity dedicated to transit. These actions often require

Table E.2
EVALUATION OF OPTIONS TO INCREASE TRANSIT CAPACITY DURING THE PEAK HOUR

Option	Time Frame	Cost	Flexibility	Targeted to Peak?	Under Whose Control?	Feasibility: Political	Feasibility: Fiscal	Feasibility: Technical/ Administrative	Appropriate for What Type of Crisis?	Practical Effectiveness	Comments
New transit vehicles	Long (2 yrs)	High ($155,000/bus)	Not Reversible	No	Operator/Local Officials	High	Low	High	Severe	Low	High cost; not directed at peak
Larger transit vehicles	Long (2 yrs)	High ($285,000/bus)	Not Reversible	No	Operator/Local Officials	High	Low	Moderate	Severe	Low	Little operating experience
Exclusive lane for HOVs	Moderate (2 wks - 1 yr)	Moderate	Reversible	Yes	Local Agencies	Moderate	Moderate	Moderate	Moderate	Low	Not effective if no extra capacity in bus fleet; cost, time-frame and feasibility depend on type of HOV
Use of privately-owned transit vehicles	Moderate (2 mos)	Moderate to High	Reversible	Yes	Operator/ Private Owners	High	Low to Moderate	Moderate	Severe	Moderate	Scant information on this action; availability of private buses unknown
Use of school buses	Moderate (2 mos)	Moderate to High ($10,000/wk)	Reversible	If school hours are changed	Operator/School District/State Legislature	Moderate	Low to Moderate	Moderate	Severe	Moderate	Conflicts with school needs likely; prior coordination suggested
Storage and/or rehabilitation of older buses	Long (in advance)	High ($1,000/bus annual storage; $100 - $3,000/ day to operate	Reversible	Yes	Operator	Moderate	Low	Moderate	Minor	Moderate	Needs to be done in advance of a crisis; maintenance will be a problem; storage space needed
Deferring non-essential maintenance	Short (immediate)	Moderate to High ($40 - $5,000)	Reversible	Yes	Operator	High	High	High	Minor	Low to Moderate	Negative effects accumulate in lengthy crisis
Adjusting routes and schedules	Moderate (2 mos)	Low ($250)	Reversible	Yes	Operator, with Local Hearings	Low to Moderate	High	Moderate	Moderate	Moderate	Public notice on hearings required; reduced service will bring opposition
Instituting or expanding express bus service	Short to Moderate (2 wks - 2 mos)	High ($800- $7,000 daily)	Reversible	Yes	Operator	High	Low	High	Minor	Moderate to High	Very effective if extra buses become available
Instituting or expanding demand-responsive service	Moderate (2 mos)	Moderate to High	Reversible	Yes	Operator/Owner of demand-responsive vehicle	High	Moderate	Low	Moderate	Moderate	Advance planning needed; administrative problems may arise
Changing service standards	Short (immediate)	Low (0 - $300 daily)	Reversible	Yes	Operator	Low	High	High	Minor	High	Assumes increased crowding is tolerable in a crisis
Changing marketing practices	Short (2 wks)	Low	Reversible	No	Operator	High	High	High	Minor	Low	Supporting action
Using other TSM techniques	Short (1 mo)	Low	Reversible	Possibly	Local Agencies	Moderate	Moderate	Moderate	Minor	Low	Not likely to affect capacity
Variable work hours	Moderate (1 wk - 4 mos)	Low to Moderate ($50,000 - $200,000 annually)	Reversible	Yes	Local Agencies	High	High	Moderate	Varies	Low to Moderate	Effectiveness depends on local factors; pre-planning most useful; transit schedules may need readjustment
Peak/off-peak fare differential	Moderate (2 mos)	Varies	Reversible	Yes	Operator/Local Agencies	Low	Moderate	Moderate	Minor	Low to Moderate	Fiscal impact depends upon type of program; flat-fare system very popular due to its simplicity

capital expenditures and may be long-term in nature. Options included in this category are:

- new transit vehicles
- larger transit vehicles
- exclusive lane for high-occupancy vehicles
- use of privately-owned transit vehicles
- use of school buses
- storage and/or rehabilitation of older buses.

New transit vehicles is an option which requires action well in advance of a crisis situation. Delivery of new buses in a crisis situation may take 24 months or more. Institutional constraints increase the delay involved in receiving delivery of new transit vehicles (14, 41). Federal procedures and regulations lengthen the procurement process, and the small number of U.S. firms engaged in manufacture of transit vehicles means that a backlog of orders can build up quickly. Consequently, this option can only be justified as part of a long-term expansion plan based on projected ridership increases; it is not a feasible response to a crisis situation. When listed in contingency plans, it is recommended only for severe emergencies (7, 10, 36). Another drawback to this option is the expense involved. Even though federal grants can pay 80% of the cost, the locally-financed cost is still in excess of $30,000 per bus, given new bus prices of $155,000.

Obtaining new transit vehicles is rated low in terms of effectiveness due to the long lead times and lack of flexibility. It is assumed that this option would be taken as part of a system expansion or modernization program; in the latter case, there is an indirect positive effect insofar as older buses can be placed in a reserve fleet. Generally, however, this option is of the wrong scale for alleviating peak-hour capacity problems in the short run.

Larger transit vehicles as an option faces the same problem as expanding the fleet: the required lead time is very long. The idea behind this option is to provide more seats without increasing labor costs. Again, this may be desirable in terms of an operator's long-term plans, but is is not feasible for a crisis situation. In terms of expense, articulated buses do not compare favorably on a per-seat cost basis with conventional buses; the latest cost estimate for an articulated bus is $285,000. However, double-decker buses are more financially practical in terms of per-seat costs (16). During 1979, Seattle indicated that articulated buses were shifted to high-demand routes, but the impact of this shift was limited by the fact that most articulated buses were already in service on such routes (37a). A recent study indicates that use of higher-capacity buses can be very beneficial in terms of reducing the number of capacity-constrained routes in the peak-hour (13a). However, the same problems noted for new transit vehicles, particularly the long lead time involved, are also present for larger transit vehicles. Additionally, there is not sufficient operating experience with larger vehicles to justify a high rating for technical feasibility. If an operator is planning to expand the transit fleet, larger vehicles may be a wise choice in terms of providing additional capacity in the event of a crisis as well as room for system-wide growth. However, the actual decision to expand must be based on factors other than the possibility of a future crisis.

Exclusive lanes for high-occupancy vehicles (HOV) are meant to reduce travel time for such vehicles and so increase their attractiveness as a mode choice. Reduced transit travel times permit more peak hour runs with the same number of transit vehicles, thus providing additional peak-hour

capacity. The extent of this effect depends upon the change in travel time; a minor decrease will have virtually no effect, while a significant change in travel time can produce significant additional peak capacity. One study suggests that an integrated program of HOV lanes could produce a peak transit capacity increase equivalent to that of providing 15 additional buses or 5% of present capacity (12). Reverse deadhead runs by the fastest route also helps to increase the number of peak-hour runs.

The general consensus in the literature concerning HOV lanes is less optimistic. Effects on travel time are considered too small to allow for any significant increase in transit capacity; excess capacity is necessary for a successful HOV strategy (33, 39). In terms of capacity-increasing options, then, provision of HOV lanes is an ancillary action which complements any option increasing the number of buses available.

One possible effect of HOV lanes is that they will attract more transit riders and so exacerbate the capacity problem. A possible opposite effect is that if the HOV lane is not restricted to transit vehicles, carpools may attract riders away from transit. Generally, evidence on the effect of HOV lanes on transit ridership is inconclusive (33, 34, 39).

There are various types of HOV lanes. A with-flow HOV action, reserving an existing lane for high-occupancy vehicle use, is least expensive; a contra-flow HOV action, reserving an existing lane in the non-peak direction for HOV use in the peak direction, is somewhat more expensive; a new HOV action, constructing a lane for HOV use, is most costly. Unfortunately, feasibility in terms of public acceptance is inversely related to cost. While there may

be little objection to construction of a new HOV lane, experience with reserving an existing with-flow lane in Boston and California clearly demonstrates the political infeasibility of such action (3, 24). Other negative factors include the cost of enforcement, which can be significant (24, 39), the possibility (greatest on with-flow HOV lanes) of decreasing the overall capacity of the roadway to move people (18), and the lead time required for construction of a new HOV lane.

With prior coordination, reserving an existing lane can be done with very little notice (28). Contingency plans, when listing this action, indicate HOV lanes to be appropriate for a moderate to severe crisis after other alternatives have been implemented (12, 22, 36). If buses are available, HOV lanes might be combined with new or increased express bus service and the effectiveness of this option would be improved. However, this option is not generally recommended for dealing with the peak-hour capacity problem, although it may be useful in circumstances of excess bus availability and corridors with heavy peak traffic in one direction.

Use of privately-owned transit vehicles expands the transit fleet by short-term rental of intercity, charter, or church buses. These vehicles can be obtained immediately in a crisis situation if prior arrangements are made, and returned at the end of the crisis. Thus, a short-term, reversible capacity increase can be achieved. However, there are several potential problems with this option (11, 12, 23, 45). It is assumed that most privately owned vehicles are used for charter trips; these vehicles are not appropriate for the stop-and-go patterns of an ordinary transit route and may be best utilized on express routes. Leasing and insurance costs could

be significant, and it would take time to complete the administrative arrangements. Since use of privately-owned buses is likely to increase in an energy crisis (e.g., people opting for chartered trips to vacation/ recreational areas instead of driving), availability may be a problem. Still, use of even a portion of privately-owned vehicles could provide the flexibility needed to handle peak-capacity problems. Further, research is needed in order to determine the feasibility of using privately-owned vehicles. Because of the current uncertainty surrounding this option and a general lack of precedents, it should be considered only in a severe crisis.

Use of school buses is an attractive option because school buses could provide a very large reservoir of publicly-owned transit vehicles. One study has indicated that if 50% of California's school buses could be used for transit, an additional 675,000 daily trips could be provided (8). Use of school buses in general transit service has not been recommended; instead, school buses have been suggested for line-haul feeder, express service from park-and-ride lots, rural service, reverse-commute runs, doubleheading (i.e., traveling immediately behind a regular-route transit vehicle to handle overflow) and combined school/commuter service (11,19, 23,27,29). However, the problems faced in use of privately-owned buses are also present here, and are in some cases more severe (1,8,11,19,20, 23,29,37a,45). The major issues regarding use of school buses are the overlap of the peak periods of school bus and transit services and vehicle design. Peak-hour capacity, particularly in the morning, cannot be expanded by use of school buses without a change in school hours (7, 12), and this is not likely to be feasible except in an extreme emergency. Interestingly, one study indicated that a shift in school hours would reduce peak transit

demand by 15%, acting as a form of flex-time, and so remove or reduce the need for expanding transit capacity by use of school buses (9). Even if a way to utilize school buses in peak hours can be found, serious design problems still remain. Small seats, narrow aisles, a single door, little head or leg room, high steps -- in short, "less than sumptuous appointments" (7) -- all make use of school buses uncomfortable at best for the transit riding public. Furthermore, the safety of standees may be jeopardized by using school buses. Substantial maintenance problems are also likely to be encountered with any significant use of school buses for transit service. Perhaps for this reason, school districts are not enthused at the prospect of leasing their buses (1, 23). A funding source for the increased operating and maintenance expenses is not clear, and financial arrangements, including fare level and collection technique, must be made between the school district and transit operator. Legal and regulatory problems concerning insurance, licensing, and prohibitions on certain uses discourage the use of school buses by the transit system. As in the case of privately-owned buses, transit labor unions must be consulted prior to use of school buses on the transit system; labor disagreements could provide an additional barrier to the implementation of this option.

Because of the many problems involved, use of school buses for transit service is generally regarded as feasible only in a severe energy emergency (5,10,12,22,23,28,36,37a). A moderate amount of lead-time is required to make the necessary institutional arrangements. The cost of leasing school buses is unknown, although it can certainly be expected to be less than the cost of purchasing new buses.

One major example of the use of school buses for transit in a crisis can highlight the problems and possibilities of this option. In June 1979, a trucker's blockade of the sole deepwater port cut off the gasoline supply in Florida's Dade County (19). For 3½ days, Metrobus used school buses in tandem with regular buses on express routes to relieve overcrowding. Institutional arrangements were worked out without much difficulty. Because both the Governor and County Manager had declared states of emergency, the drivers' unions did not have to be consulted, although strong objections from the Metrobus drivers' union were noted on record. Insurance was the major cost: of the $9,000 deficit incurred in the 3½ day period, $7,500 was due to insurance requirements. Riders reacted positively to the increased availability of transit and tolerated the design problems in the short term. Overall, the use of school buses was successful in Dade County, but Metrobus does not feel that school buses are acceptable in the long term (10 days or longer) or are suitable for regular use. The fact that this crisis occurred when school was not in session prevented some of the potential problems with implementing this option, but now that Metrobus has acquired additional vehicles, there is little interest in repeating 1979's use of school buses.

Storage and/or rehabilitation of older buses is an option intended to provide reserve vehicles for an emergency at a fraction of the cost of a future purchase of new vehicles. Previously, when transit operators purchased new buses with UMTA funds, they were required to sell the buses being replaced; current UMTA policy permits stockpiling of older vehicles for use in an emergency. In this way, a reserve bus fleet may be gradually established in advance of a crisis situation, and the transit operator will be able to respond quickly when capacity expansion is necessary.

This approach is not without its problems (12,25,28,37a,41). The stockpiled vehicles must be kept in near-operable condition; this will increase maintenance and labor costs, and may be more difficult than anticipated. Adequate storage facilities are necessary. The cost of this action is uncertain. One study estimates the cost per bus at $750 for one year in 1979 dollars (25), but the expense involved in storing, maintaining and possibly rehabilitating these vehicles is likely to be higher. The expense and required storage space are the chief negative factors regarding stockpiling, although there is also a feeling that it is a difficult action to justify in practice. A transit operator faces continuous requests for additional service; refusing these requests is more difficult if a reserve fleet is in fact available. Where it is included in contingency plans or recommended in reports, use of stockpiled buses is generally suggested as appropriate for minor shortages or for the early stages of more severe shortfalls (5,10,12,28,36). A capacity increase of 10% is seen as feasible. The time frame for stockpiling is long-term: by the nature of the action, pre-planning is necessary and continual maintenance is required.

Where a reserve fleet of buses has been brought back into service, the older buses were found to break down frequently. Stockpiling of older buses for use in an energy crisis was judged as relatively ineffective as a capacity-expanding option (37a). Improving in-storage maintenance could increase costs prohibitively. In short, while there are many attractive features in the stockpiling option, there are also many problems to be solved. It should be noted, however, that survey respondents which had some kind of reserve fleet available in 1979 rated this action as moderately effective despite the associated problems.

The options identified here take what might be termed a "traditional" approach to transit capacity expansion. They involve either the acquisition by the transit agency of more or larger vehicles or an increase in roadway capacity devoted exclusively to transit. None of these options is inherently oriented toward the peak hour. It is not surprising that they are accorded relatively low priority in contingency plans. While the obstacles involved are not insurmountable, these options tend to rank poorly in terms of feasibility.

Change in Operations

This broad category encompasses most of the peak-hour capacity-expanding options, particularly the short-term ones. In institutional terms, these options can be taken in most cases by the transit operator, without involving outside agencies. Actions in this category deal with operating and maintenance procedures and policy issues. The options include:

- deferring non-essential maintenance
- adjusting routes and schedules
- instituting or expanding express bus service
- instituting or expanding demand-responsive services
- changing service standards
- changing marketing practices
- using other TSM techniques

Deferring non-essential maintenance is a short-term tactic to get buses out of the shop and into the streets. It has been recommended as a low cost option for a minor or moderate shortfall (5,8,22,36,41). Obviously, it would not be appropriate for a long crisis period, although it could also help in a severe emergency of short duration. Most transit operations have

a spare ratio approximating 20%, i.e., 20% of their buses are in the shop at any one time. While mechanical problems must be dealt with immediately, cosmetic or preventive maintenance could be deferred in an emergency. Assuming that the fleet is in reasonably good condition, deferring non-essential maintenance could reduce the spare ratio to 10% or even to 5%. This could result in an immediate increase in capacity of 10% to 15% (12, 28, 37a). Of course, deferring preventive maintenance could lead to an increase in future problems and expenditures, but this is a risk often worth taking in a short emergency. It can also serve as a stopgap measure in a long-term crisis while other options are prepared. Other changes in maintenance practices (such as altering schedules or "jobbing out" maintenance to outside agencies) may also be effective in increasing peak capacity, but increased overtime and labor expenses (on the order of $5,000 per vehicle in 1975 dollars) are likely to result (26). The time limit during which non-essential maintenance can be deferred without creating more serious problems is not clear, and the difference between essential and non-essential maintenance is not specifically defined. Miami's experience in 1979 indicated that after two weeks, the number of breakdowns exceeded the number of additional vehicles provided by deferring non-essential maintenance.

If the crisis threatens to last longer than anticipated, non-essential maintenance can be resumed at longer intervals: this allows the spare ratio to rise but keeps it below its original level. Some long-term maintenance problems may thus be averted or lessened. This action appears to be feasible for most transit operators. For example, in 1979, the Dallas Transit System changed its preventive maintenance cycle from every 9,000

miles to every 12,000 miles and obtained 25 extra buses daily, thus increasing the fleet size in peak periods by 6% (37b).

A major positive aspect of this option is that it can be taken immediately. A lengthened maintenance cycle in lieu of indefinite deferral may keep costs down and avoid or lessen the severity of intermediate-term problems. However, deferring non-essential maintenance was generally found to be of low to moderate effectiveness, with effectiveness decreasing over time.

Adjusting routes and schedules is an ongoing process, but in an emergency certain types of adjustments should be considered. Several alternatives have been suggested (6,8,10,17,22,23,28,36,37a,41). These include: shifting buses from low-demand to high-demand routes, adjusting schedules accordingly; increasing the number of turnbacks prior to the end of a route; shortening routes; doubleheading, or running two buses in tandem; skip-stop service; reverse-commute runs; returning directly to the start of peak-direction route via expressway in order to get more peak runs per bus. Doubleheading and skip-stop service require additional vehicles to be effective in increasing capacity. Reverse-commute runs may also require additional vehicles unless high-demand reverse routes roughly aligned with existing routes are found. The other options are intended to provide more peak-direction buses along high-demand corridors during the peak hour. Schedules may also need adjustment if a major employer changes to staggered work hours or flex-time. A major overhaul of routes and schedules is not recommended; this would merely add to the confusion of a crisis period.

One study indicates that actions of this nature are often part of a contingency plan yet are rarely implemented (37a). This suggests that there are certain problems with this option. Perhaps the basic problem is that in a steady-state environment, an increase in service in one area means a decrease in another. While these actions attempt to confine service cuts to the least-utilized portions of the system, in a crisis situation even the least-utilized routes are likely to be experiencing ridership increases. Service cutbacks are extremely difficult to justify when additional people need that service more than ever (36). This is the reason why some studies recommend adjusting routes and schedules only in extreme emergencies, although most studies which recommend these actions suggest they be taken in moderate crises (5,10,22,23,36). Even then, if near-capacity loads are experienced throughout the system, there would be little flexibility in routing and scheduling.

Another problem hindering implementation of these actions is the time frame involved. Public hearings are usually required, and scheduling is a complex, time-consuming process. The public must be notified of any routing or scheduling changes. These problems suggest that it is necessary to plan detailed routing and scheduling changes in advance of a crisis as part of the contingency planning process. In a crisis, a transit system is likely to come under close scrutiny; it may be best not only to plan but also to make any necessary changes in routing and scheduling before a crisis occurs. The current fiscal atmosphere will encourage this process, but the transit operator may feel that certain changes are necessary only in an emergency. It may be possible to gain advance approval for contingency actions and so reduce the time needed to institute a given action. While the effectiveness

of this action is moderate, it is likely to provoke negative publicity for the transit operator.

Instituting or expanding express bus service is usually considered an action which attracts peak-hour riders, not one which eases capacity problems. In certain cases, however, it could increase peak capacity. Consideration should be given to conversion of local routes to express, especially if a large portion of the route's ridership boards on the outlying part of the route or if additional local service is available nearby. As noted in regard to HOV lanes and routing and scheduling changes, more peak-direction bus trips per peak hour is possible if route length or travel time is reduced, thus increasing peak-hour capacity. Feasibility of this option in terms of increasing capacity is dependent on the demand characteristics of the route. Of course, if extra buses become available (e.g., through leasing intercity buses), then expanding express service may be the best way of utilizing this increased capacity. However, expanding express service in the absence of other actions is not a promising capacity-expanding option. Where mentioned in area contingency plans, express bus service is thought to be appropriate for a minor or moderate crisis (10,22).

Instituting or expanding express bus/park-and-ride service received a surprisingly high effectiveness rating from the survey respondents. It was also the most costly option, with a program of this nature averaging over $4,000 per day (see Table D.4, p. 61 and Table D.7, p. 64). If extra buses do become available in the crisis and if money is at hand, this option can be very effective.

Instituting or expanding demand-responsive service can be an effective way to deflect some of the increased demand from regular bus service and to provide flexibility in the use of the existing bus fleet (11, 17, 28, 46). Actions included in this option are: to permit taxis to offer shared-ride instead of premium (single-passenger) service; to use taxis for feeder service to line-haul bus routes, either as jitneys (i.e., fixed-route demand-responsive) or as shared-ride taxis (no fixed route); to substitute jitney service for regular buses on lightly-traveled outlying portions of existing routes; to encourage employers to institute subscription bus service for their employees. Transit operators have often objected to proposals allowing shared-ride taxi service. The regulatory agency would be more likely to look favorably on such a change if the transit operator dropped any objections to it, at least in a crisis situation. Taxis would thus be able to absorb more of the increased demand for public transportation. The second and third options would to some extent integrate taxi/jitney service into transit operation. Feeder service by taxis or jitneys would be feasible only if line-haul capacity is sufficient; this action is aimed more at increasing ridership than expanding capacity. Substitution of jitney for fixed-route service, however, provides flexibility to the transit operator: either more peak-direction trips can be made along the main portion of the route in the peak hour or buses may be reassigned to other routes as needed, and there is no significant decrease in service provided. Subscription bus service, if adopted by employers, could ease capacity problems on routes serving major work sites.

However, it has been noted that demand-responsive services are frequently mentioned as an alternative but rarely implemented (37a). Local laws and

regulations often prohibit shared-ride and jitney services (11, 45). Labor problems arise because of Section 13c provisions. Local funding sources may have to be found and equitable fare arrangements worked out, particularly in cases where demand-responsive service replaces conventional service. Finally, there is the question of the availability of taxis to augment the transit fleet. It should be possible to make arrangements to overcome these problems in advance of a crisis, and with proper planning, demand-responsive service may indeed be a feasible option. Currently, this option is considered appropriate for a moderate to severe crisis (22, 23, 36), although it is difficult to evaluate because it is virtually untried in a crisis situation. While it is theoretically an attractive option, it must be prepared in advance in order to provide time to resolve the various administrative problems likely to arise.

Carpooling also deserves mention in this category. While carpool programs are often viewed as competing with transit services for the same small pool of potential patrons, this is exactly the reason why carpool programs could help alleviate transit capacity problems when that pool grows suddenly. Operators could make pamphlets promoting carpool programs available to transit riders. Transit operators might justifiably worry about the long-term wisdom of this approach, since they may find lower-than-expected ridership levels in the post-crisis period if a sufficient number of transit riders switch permanently to carpooling. From the operators' point of view, the best strategy is to do nothing in regard to carpooling, to let others promote it while they promote the benefits of transit. The operators are caught in a dilemma: capacity problems are likely to discourage ridership in the long run, but active promotion of carpooling programs will do this

also. Unless the crisis is extremely severe and prolonged, operators will probably stay away from carpooling programs. Promotion of such programs by others, however, will deflect some of the increased demand for public transportation and so have a beneficial effect on peak transit capacity.

Changing service standards is a "default" option in the sense that if nothing is done, service standards will probably be lowered as load factors increase. Some operators make a conscious decision to allow less rigorous service standards in an emergency by raising the acceptable passenger/seat ratio or by allowing a greater percentage of buses to exceed that ratio (10, 41). It is often assumed that passengers will tolerate increased crowding in a crisis. This does not increase capacity as defined in Section 1, but it is an effective option, especially where existing service standards are strict. In 1979, it was the action most often taken by transit operators, and because of its low cost and immediate time frame, it is recommended as the first action in any crisis. Allowing more crowded buses gives the transit operator additional time to monitor the energy situation, to finalize plans for action and to do any necessary pre-implementation work (e.g., prepare a reserve fleet for return to service).

Changing marketing practices will not in itself affect capacity, but it is useful as a supporting action. Instead of general promotion, marketing dollars might better be targeted for passenger information services which can provide potential riders with specific answers (17). The benefits of riding in the off-peak whenever possible can also be emphasized (33). If the peak-hour capacity problem is severe and routing or scheduling changes are being implemented, this option is virtually a necessity.

Other TSM techniques such as signal retiming, priority entry for buses on metered freeway ramps, and improved traffic management increase bus speed by so little that no extra peak trips are likely to result. These need not be considered further in this report.

Changes in operations are under the control of the transit operator, require no expenditures for new equipment, and generally can be implemented quickly. Many are quite effective in expanding peak-hour capacity, and while there are certain problems involved, these options should be among the first considered in a crisis.

Shift in Demand

Unlike options included in the other two approaches, the actions involving a shift in demand do not attempt to increase capacity. Rather, they seek to manage the peak-demand problem by spreading this demand over a larger period. The goal of these actions is a reduction in peak demand through shifting a part of that demand to the "shoulders" of the peak or to the off-peak. If peak demand is reduced, peak capacity need not be increased. (This is sometimes erroneously referred to as supply-side transportation.) Smoothing the peak results in a more efficient transit operation even in the absence of a crisis. In an emergency, it is highly desirable in order to reduce the strain on the transit system.

The two actions contained in this category are:

- variable work hours
- peak/off-peak fare differentials

Variable work hours can take many forms. Hours can be chosen by the employee or employer, the work week can be 4 or 5 days, a given employee's starting time and work day length can be fixed or flexible. These different forms need not concern us here; the important fact is that the peak-hour transit demand is lessened. A large part of peak-hour transit travel is work-related; variable work hours shift a portion of the peak-hour demand to the off-peak, when most transit systems have excess capacity.

Many studies and reports have examined some aspect of variable work hours as it relates to transit capacity (2,7,9,10,12,15,17,20,22,23,28,30,32,33, 35-38,41,43-45). The increased attention accorded to low-capital solutions to transportation problems and changing work habits have made variable work hours an attractive alternative. However, putting together a variable work hours program still involves a great deal of coordination. Such a program is easier to implement in cities dominated by public sector employment. If there is a significant number of large private employers, at least one full-time contact person is necessary to promote the concept and deal with any problems. One possible program would be to make variable hours mandatory for the public sector and encourage alternative work schedules in the private sector.

It is expected that a variable work hours program would receive higher priority in larger cities, where peak transit crowding is more severe. The program can be targeted to meet the most serious problem, in a specific neighborhood or along a specific transit route, or it can be implemented in the entire CBD area (assuming that crowding is most severe in the CBD). Success of variable work hours is usually measured by the percent of the

target area's work force participating and by the reduction in arrivals during a given interval of the peak hour (most often the peak 15 minutes).

Variable work hours can have a major positive impact on peak-hour congestion. In the peak 15 minutes, passenger and vehicle loads at transit terminals have been reduced by 15 to 35%, and bus passenger loads by as much as 29%. Variable work hours seem more effective than peak-hour pricing in changing peak demand. Overall peak-hour demand is also reduced. The greatest impact appears to be on radial transit routes, as decreased congestion is noted all along the routes. The impact of variable work hours is also very noticeable in small and medium-sized cities.

Instituting variable work hours has other effects. Travel time is reduced for all modes. There is some evidence that transit's mode split could increase; conversely, additional surveys indicate the possibility of a shift from transit to single-occupant automobile. The general conclusion is that transit ridership levels are not affected one way or the other by implementation of variable work hours. Employees report very high levels of satisfaction with variable work hours, while employers are also pleased, noting improved morale and increased productivity in many cases.

Participation rates in variable work hours programs range from below 10% to nearly 50% of workers in the CBD. Fewer workers participate in the 4-day workweek, although it seems to be increasing in acceptance. Participation is greater in places where public-sector employment predominates. Beyond these generalities, it is difficult to predict participation rates; 20 to 25% of CBD or target area workers seems a reasonable goal.

The cost of implementing a variable work hours program is generally considered minor, especially in relation to the benefits received (15,30, 33,43,45). An annual cost of $50,000 to $200,000 can be expected for an aggressive program involving many private employers. If there is significant public sector employment, cost would be lower. This cost is not borne by the transit operator, but by the public agency responsible for the variable work hours program. The benefits of the program, of course, are not confined to transit.

There are problems faced by transit operators, employers, and employees in the implementation of variable work hours. While demand is smoothed at the height of the peak, demand often increases at the "shoulders", near the beginning and ending times of the peak period. Peak-hour headways may need to be maintained for longer periods of time. Additional vehicles may be required to achieve this; otherwise, demand will be shifted to times when adequate service is not provided, and the transit system could lose riders. On large systems, it is possible to make these adjustments after problems are noted, since the level of service in the "shoulder" portion of the peak period is fairly high. Moderately-sized and smaller systems should adjust service in coordination with the institution of the program, but the source of additional vehicles is not clear. If scheduling permits, vehicles in service during the current peak interval can be kept in service for a longer period (i.e., 3 runs instead of 2).

Analysis of two unsuccessful variable work hours programs reveals other problems (40). London's 1959 program involved only 2.1% of CBD workers and participating firms were widely scattered throughout the CBD. There was no

prior consultation with organized labor or the merchants' association, resulting in opposition from both business and labor. Atlanta's 1968 program also met with opposition from both parties in the workplace: employers feared problems with delivery of goods and communications and cited restrictive nationwide labor contracts, while employees felt that carpool arrangements and transit commuting patterns would be disrupted. In both cases, lack of coordination and cooperation with business and labor interests and transit agencies played a large part in the program's failure. This emphasizes the need for pre-planning involving employers, employees, and transit operators in order to make a variable work hours program effective. A moderate amount of lead time ranging from 2 to 4 months is necessary before implementing a variable work hours program (in order to obtain the cooperation of all parties). This need for extensive preparation and coordination is the reason why variable work hours is an often-mentioned but rarely-implemented option.

There is no general agreement on the severity of the crisis for which variable work hours is an appropriate option. A 4-day workweek is considered the most drastic work hour option and is reserved for a severe crisis. Some analysts concerned with transit operations view a shift in peak demand as the first course of action, while others feel that actions within the control of the transit agency should be pursued before variable work hours are considered. The view taken may depend upon the employment patterns of the city in question. As mentioned earlier, cities with significant public-sector employment and larger cities with dense CBDs provide the most conducive settings for a variable work hours program. Service, manufacturing, and large retail firms are the most likely

businesses to embrace variable work hours in the private sector, although flextime (allowing employees to determine their own work hours) would be ruled out in these cases. While some communications problems may arise with a variable work hours program, many employers find the benefits of improved employee morale to outweigh minor communications problems. Flextime is obviously preferable to other programs for employees; the ability to set work hours also eases problems with carpool arrangements. Cooperation with transit operators can overcome possible service problems arising from variable work hours. In short, the problems inherent in a variable work hours program are amenable to solution with careful pre-planning, but such a program will be more effective in certain localities than in others, depending upon city size, density, and employment patterns. It is also necessary for some agency to be willing to take the lead in the coordination and implementation of a variable work hours program.

Variable work hours programs implemented in Lower Manhattan, Ottawa and Toronto are cited most often in the literature. Several measures have been used to gauge the effectiveness of such programs (30, 32, 43). Although the measures are not strictly comparable, all show a reduction in peak demand. Evidence from Manhattan and Toronto indicates overwhelmingly favorable response from employees. Participation rates are highest in federal or state government centers (47% of CBD employees in Ottawa, 40% in Washington D.C., 30% in Madison, Ws.).

There is one interesting example which contradicts the assumption that a significant amount of lead time is necessary to develop and implement a variable work hours program (20). In response to the 1978 Great Blizzard in

Boston, the Governor's Office and the MBTA asked major employers to go on a staggered work hours schedule which they had designed. Firms were assigned work hours depending on the type of business (e.g., manufacturing, production and municipal workers were asked to report at 7 a.m., state workers at 11 a.m., and other employees at specific hours). While there is no information on how many firms cooperated, MBTA noted a spreading of the peak on the two critical days immediately following the storm. MBTA was able to handle ridership increases of 39% and 29% on these two days with below-normal capacity due to storm-related equipment problems. While a blizzard is not quite comparable to an energy crisis in terms of time frame and public perception, the Boston experience suggests that if government officials are willing to take the lead role in a crisis situation, it may be possible to respond more quickly than anticipated.

In general, a successful variable work hours program requires considerable planning, although if the crisis is severe enough, a hastily-arranged program can work. Such a program is most successful in large cities with densely-developed CBDs and in cities with a significant amount of public-sector employment. The costs of such a program might vary from $50,000 to $200,000 for the first year, but this cost is not borne by the transit operator. On the other hand, the operator has no control over implementation of this option. Generally, a four-day work week is considered appropriate only for a severe crisis, while other variable work hours programs are appropriate for a minor crisis. Survey respondents ranked variable work hours programs low in effectiveness, but the programs seemed to produce moderate shifts in demand from the peak to the "shoulders" and

off-peak. The transit operator must ensure that service in the shoulders of the peak is adequate to handle the shift in demand.

Peak/off-peak fare differentials are also intended to reduce peak demand. By either reducing off-peak or raising peak fares, the transit operator can induce some peak-hour riders to switch to the off-peak and discourage peak-hour discretionary travel. Evidence from non-crisis situations indicates that off-peak fare reduction programs have been successful in shifting demand out of the peak (32). Generally, however, transit patronage is inelastic with respect to fare, especially in the peak hour (16, 21, 32). It is difficult to predict the extent of the impact of a fare differential on peak demand in a crisis, given these contradictory statements. In past energy crises, the supply of gasoline was a much more important factor than its price in determining mode shifts from automobile to transit. If the situations are indeed analogous, then the availability of transit service would be more important than fare levels, and a peak/off-peak differential would not have a significant effect on peak demand.

This hypothesis is supported by the fact that this option is often recommended in contingency plans, but rarely implemented (37a). Financial considerations argue against reduced off-peak fares in a crisis, since this reduces revenue at a time when money is needed. From a fiscal point of view, raising peak fares is both desirable because it increases revenue and justifiable because providing peak service is a large part of a transit operator's costs. However, it is not the most politically feasible option. The end result is that fare differentials have not been established in response to a crisis.

Most of the contingency plans which include this option consider it appropriate for a minor crisis (10, 12, 22, 23). The shift in demand to the off-peak, the efficiency arguments that peak riders should pay more for service that costs more, and the extra revenue generated by raising peak fares are all attractive arguments in favor of peak/off-peak fare differentials. However, uncertainty regarding the magnitude of demand shift, political and public relations problems with obtaining approval of a peak fare increase at a time when more people are dependent upon transit, and the loss of revenue from a reduction in off-peak fares have all led to hesitation on the part of transit operators in implementing this option in response to a crisis. With increasingly sophisticated fare collection equipment, a differential fare structure is likely to become easier to understand and simpler to use. However, a crisis situation is not the best time to introduce such a change. If a differential fare structure is already in effect and well-understood, it might be reasonable to increase the difference between peak and off-peak fares for the duration of a crisis, although given the elasticities discussed above, the effect of such an action may be minimal. No survey respondents reported any experience with differential peak/off-peak fares in 1979.

Both demand-shifting options hold theoretical promise, and there are examples of successful implementation of both options in non-crisis situations. However, these options are not panaceas; successful implementation requires a great deal of careful planning and coordination, and there is limited practical experience, particularly in crisis situations. The transit operator is not the only or even the most important actor in the design and implementation of actions in this category.

Partially because of this, and partially due to lack of experience with these options, transit operators are not unanimous in their opinions. While some embrace the idea of spreading peak demand as an attack on the capacity problem at its source, others prefer to take actions completely under their own control before venturing into untested waters. As experience accumulates and more and better data are available concerning these options, it is likely that they will be more widely accepted and implemented.

Summary

Obvious differences in the approaches to the peak-hour capacity problem are apparent. The traditional fleet/roadway expansion approach involves high-capital, long-term actions not specifically oriented toward the peak period. The operations approach focuses on TSM-type actions which are generally low-cost, short term, reversible and totally within the control of the transit operator. The demand-shift approach is radical in the sense that it circumvents the traditional approach by going to the root of the problem.

In presenting options, this report has incorporated both long-term and short-term actions. On the survey, transit operators recommended several options which were not implemented in 1979 due to time problems. Given available lead time, these long-term options are as important as short-term options. Therefore, this analysis was designed to evaluate a complete list of peak capacity-expanding options.

Table E.1 summarizes the differences in the approaches to the peak-hour capacity problem. The evaluation of each of the capacity-increasing options

is summarized in Table E.2. In evaluating the options, operators' responses in 1979 were utilized along with general information and examples from the literature. The evaluation formed the basis for the packages and recommendations in Section 3. This appendix has been aimed at those who need a more in-depth analysis of capacity-expanding options.

APPENDIX F

Derivation of Capacity Problem Index

The magnitude of peak-hour ridership increases and the excess transit capacity available during the peak-hour are the determining factors in addressing whether a transit system does or will experience a peak-hour capacity problem. A Capacity Problem Index can be developed to measure the level of ridership increase at which a problem will occur.

As a first step, consider the current peak-hour load factor (PL) on a given route. The excess capacity available on the route in the peak-hour can be expressed as (1-PL). The percentage increase in peak-hour ridership (PR) which can be accommodated on the route is:

$$PR = \frac{(1 - PL)}{PL} \cdot 100 \qquad (F.1)$$

If the peak load factor is 0.9, then an 11% increase in peak ridership can be accommodated. If the peak load factor is 0.75, then a 33% increase in peak-hour ridership can be tolerated.

Equation F.1 gives the percentage increase in peak-hour ridership at which all seats will be occupied. In establishing schedules, most transit operators allow for some crowding in the peak-hour up to an acceptable limit. This acceptable peak load factor (APL) is usually in the range of 1.2 to 1.5, although some contingency plans allow it to rise to 1.7 in a crisis. Equation F.1 can be modified to take into account a system's acceptable peak load factor as follows:

$$PR = \frac{(APL - PL)}{PL} \cdot 100 \qquad (F.2)$$

A route with a peak load factor of 0.9 and an acceptable factor of 1.2 can accommodate a 33% increase in peak-hour ridership as opposed to an 11% increase if no standees are tolerated. Note that the option of changing service standards merely involves increasing the value of APL. If 1.5 is the acceptable load factor and 0.9 is the current peak load factor, a peak-hour ridership increase of 67% can be accommodated.

Equation F.2 provides the percentage increase in peak-hour ridership that will cause a capacity problem, given current and acceptable peak-hour load factors on the route. Optimally, a capacity problem index would indicate the level of increase in overall ridership that triggers a peak-hour capacity problem. This overall ridership increase, measured as a percentage, would be lower than the peak-hour percentage increase, since the additional ridership generated by an energy crisis tends to be focused on the peak-hour. It is reasonable to assume that the ratio of percentage increase in peak-hour ridership (PR) to percentage increase in overall ridership (R) is constant for a given transit route or system (and perhaps across transit systems). Mathematically, this can be expressed as:

$$k = \frac{PR}{R} \qquad (F.3)$$

This can be broken down to:

$$k = \frac{\frac{\Delta PR}{PR_o}}{\frac{\Delta R}{R_o}} \qquad (F.4)$$

where ΔPR is the change in peak-hour ridership

PR_o is the existing peak-hour ridership

ΔR is the change in overall ridership

R_o is the existing overall ridership.

Adjusting Equation F.4 yields:

$$k = \frac{\Delta PR}{R_o} \cdot \frac{R_o}{\Delta R} = \frac{\Delta PR}{\Delta R} \cdot \frac{R_o}{PR_o} = \frac{\frac{\Delta PR}{\Delta R}}{\frac{PR_o}{R_o}} \qquad (F.5)$$

Note that $(\Delta PR/\Delta R)$ is the proportion of overall ridership increase occurring in the peak-hour, while (PR/R) is the existing peak-hour share of overall ridership. If we let:

$$i = \frac{\Delta PR}{\Delta R} \qquad (F.6)$$

and

$$p = \frac{PR_o}{R_o} \qquad (F.7)$$

then

$$k = \frac{i}{p} \qquad (F.8)$$

There is some evidence that the proportion of overall ridership increase occurring in the peak-hour (i) is constant. The 1980 Crossley Empire State Poll revealed that the number of people switching modes to transit for work trips was approximately equal to the number of people switching to transit for non-work trips (13). The survey considered 4 separate regions of New York State and in each the proportion of transit ridership increase attributed to work trips was between 45 and 50% of the overall increase. If we assign work trips to the peak-hour and non-work trips to the off-peak, then:

$$i = 0.5 \qquad (F.9)$$

is a reasonable approximation of the proportion of overall ridership increase

occurring in the peak hour. With this value of i, k may be expressed as:

$$k = \frac{0.5}{p} = \frac{PR}{R} \qquad (F.10)$$

Recall that R is the percentage increase in overall ridership that will trigger a peak-hour capacity problem. R can be expressed as:

$$R = \frac{PR}{k} = \frac{PR}{\frac{0.5}{p}} = PR \cdot \frac{p}{0.5} = PR \cdot 2p \qquad (F.11)$$

or (substituting Equation F.2 for PR):

$$R = \frac{(APL - PL) \cdot 200 \cdot p}{PL} \qquad (F.12)$$

Equation F.12 is the form which the Capacity Problem Index takes to determine the critical level of ridership increase, and is identical to Equation 2.1 in the text. Since peak load factors vary by transit route, this index is best applied on a route-by-route basis, although it may be applied on a group of key routes with similar peak-load factors.

A previous study developed cross-elasticities of transit ridership with respect to gasoline supply for various system sizes and regions of the county (4). Although these cross-elasticities were developed at a very aggregate level, they may be used to give a rough estimate of the magnitude of gasoline shortfall at which a peak-hour capacity problem will occur. Table 2.1 in Section 2 lists the cross-elasticities. The percentage gasoline shortfall (G) which will trigger a peak-hour capacity problem is expressed as:

$$G = \frac{R}{e} = \frac{(APL-PL) \cdot 200 \cdot p}{PL \cdot e} \qquad (F.13)$$

where e is the appropriate cross-elasticity.

Equation F.13 is the form which the Capacity Problem Index takes to determine the critical level of gasoline shortfall, and is identical to Equation 2.2 in the text.

Generally, Equation F.12 (or 2.1) is used in a crisis situation where ridership increase is already occurring. In a crisis, if R is positive then the route is accommodating the increased ridership. In a pre-crisis situation, Equation F.13 (or 2.2) is used to plan for shortfalls of various magnitudes.

Note that the CPI is applicable to the AM peak-hour, the PM peak-hour, or both. If either the AM or PM peak is considered more significant or if data are only available for one, then the operation need only make sure that all necessary data inputs reflect only one peak-hour. Alternately, if both the AM and PM peak-hours are of concern, both can be analyzed together. The value of p, the proportion of overall ridership carried in the peak-hour, will obviously be greater if both peaks are analyzed together. While calculation of p for the route under question is ideal, a systemwide value is also acceptable. Generally, the AM and PM peak-hours or more than one route may be analyzed together as long as their peak load factors are very similar. If this is not the case, separate analysis is recommended.

Application of the Capacity Problem Index is discussed in Section 2.

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